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THERMAL
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MANUAL NO. 147

Also:
A Guide to Standards
New Semiconductor Material
Selecting Wire Cloth
Complete Contents—page 1

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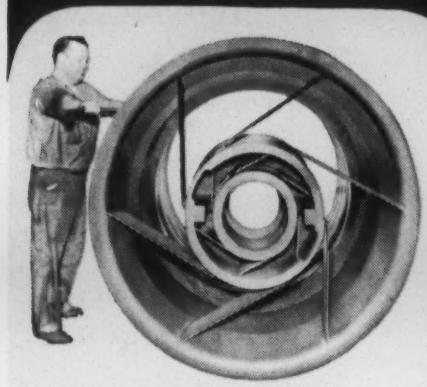
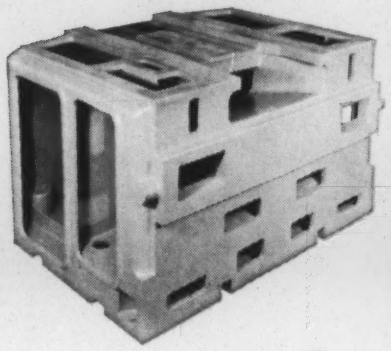
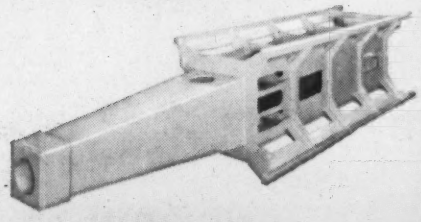
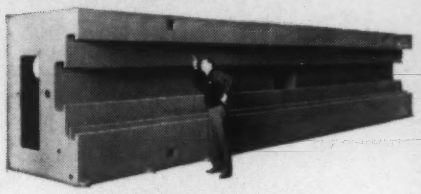
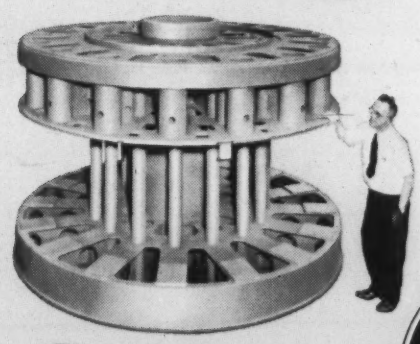
MARCH, 1958

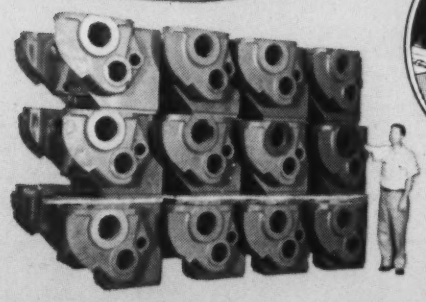


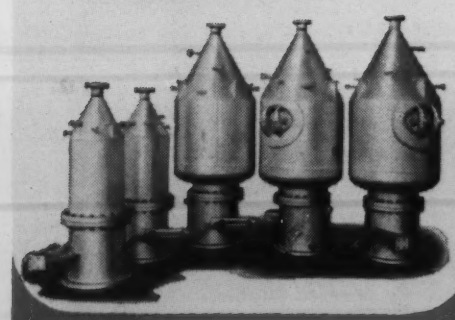




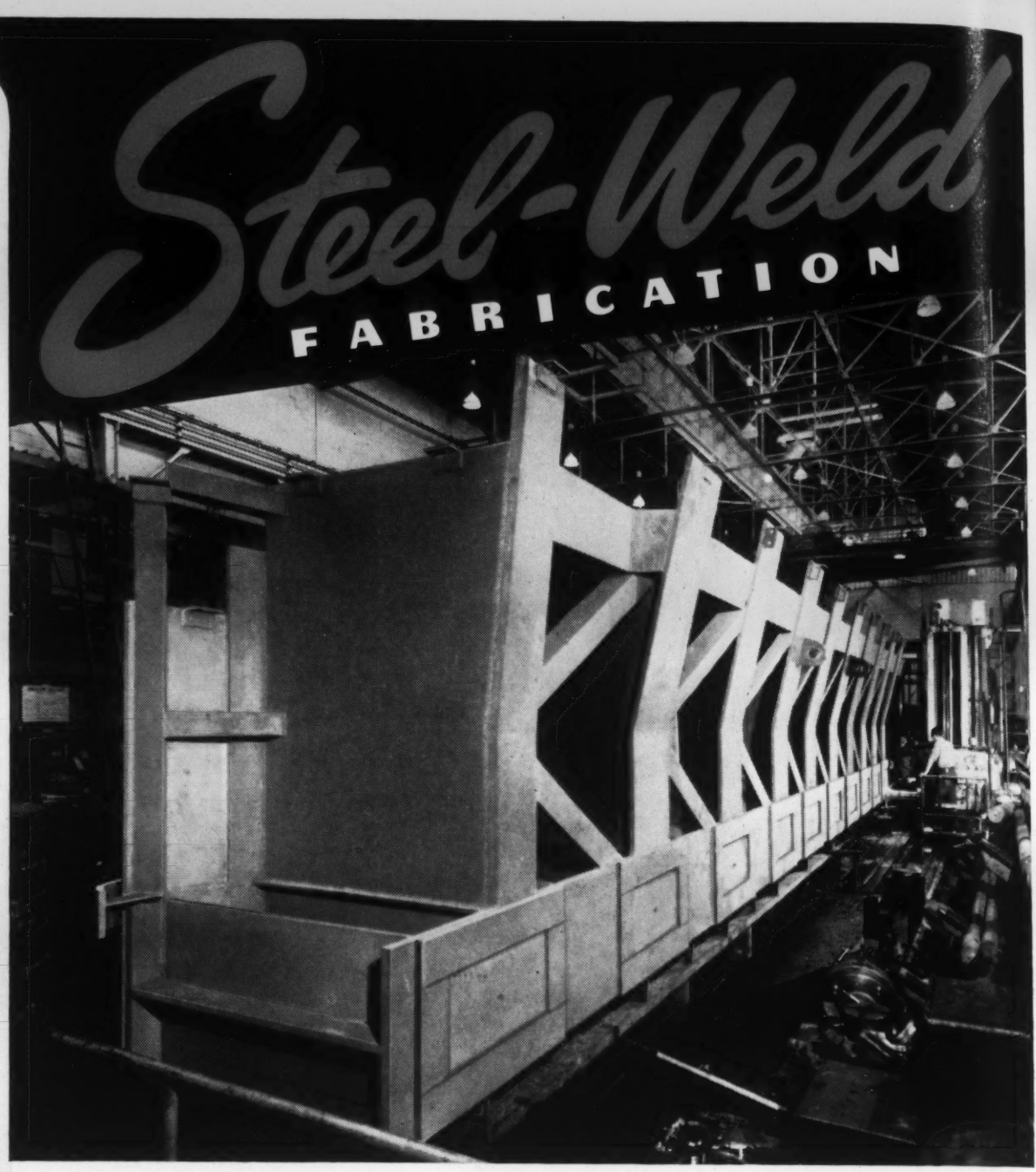








Steel-Weld FABRICATION



Use WELDED STEEL for Greater Strength with Less Weight!

The 46-Ton Weldment, illustrated above, is one of two Reaction Girders which, after machining, will become integral parts of a 390-Ton Vertical Lift Gate in a Lock Mechanism in the Long Sault Canal at Massena, New York. Mammoth Weldments such as this Lift Gate, and the diverse pieces at left, are typical of the thousands of Steel-Weld Fabricated parts and assemblies produced by Mahon each year for use in processing machinery, machine tools, and other types of heavy mechanical equipment. If you are not now taking full advantage of the economies offered by welded steel components in your product, you should give the matter serious thought. In the design of almost any type of heavy machinery there are parts and sub-assemblies that can be produced more economically, more satisfactorily, and in less time, in welded steel. In weldments you get greater strength with less weight—plus the additional advantages of greater rigidity and 100% predictability. When you consider weldments, you will want to discuss your requirements with Mahon engineers; because, in the Mahon organization you will find a unique source for weldments or welded steel in any form ... a fully responsible source with complete facilities for design engineering, fabricating, machining and assembling. See Sweet's Product Design File for information, or have a Mahon sales engineer call at your convenience.

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Materials
in Design Engineering® *formerly Materials & Methods*

Selection & use of metals, nonmetallics, forms, finishes

MARCH 1958
VOL. 47, NO. 3

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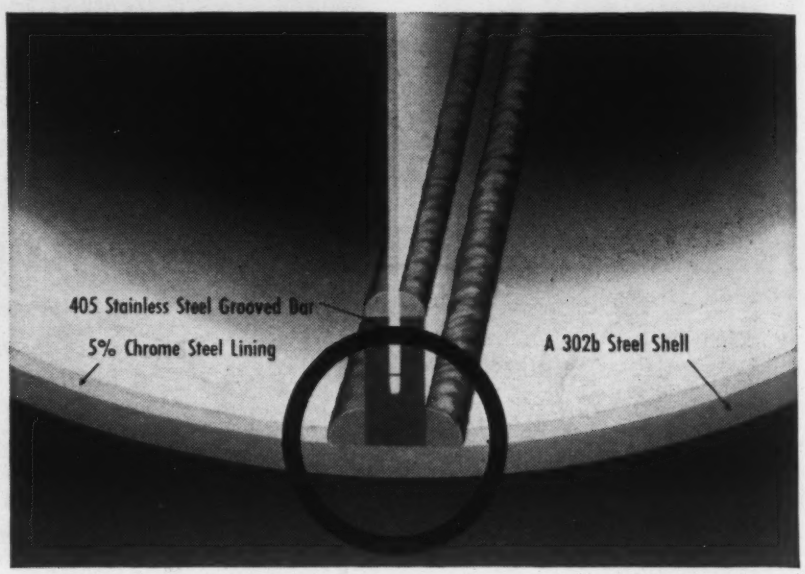
COVER BY HARRY & MARION ZELENKO

Weld: 304 stainless to mild steel
Conditions: chloride corrosion **Equipment:** drag conveyor

Weld: Inconel* nickel-chromium alloy to ordinary steel
Conditions: high temperature **Equipment:** furnace retort

Weld: repair of cracks in carbon-molybdenum steel
Conditions: no preheat possible **Equipment:** throttle valve



Weld: 405 stainless to 5% chrome steel and A302-B steel
Conditions: high pressure **Equipment:** pressure vessel

Now one electrode, Inco-Rod "A", ...permits new design freedom

No longer need difficulty in welding dissimilar alloys limit design possibilities.

With Inco-Rod "A"* electrode, "problem" welds like those above are being made every day — without special equipment and without special training for weldors. Many users also report remarkable success with Inco-Rod "A" electrode in field welds where preheating is impossible.

Dissimilar alloy welds made with Inco-Rod "A" electrode are strong, ductile and resistant to corrosion in many media. They have high impact resistance at sub-zero temperatures and good stress rupture properties at elevated temperatures.

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To get a clearer idea of the jobs Inco-Rod "A" electrode can do, write for our new folder. It contains many case histories and gives useful tips on getting strong, sound, corrosion-resisting welds between dissimilar alloys.

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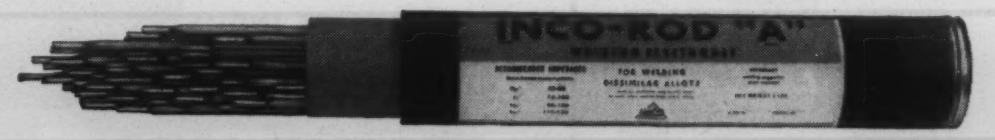

Inco-Rod "A" electrode is supplied in four diameters: 3/32-, 1/8-, 5/32-, and 3/16-inch . . . packed in 5-lb. asphalt-lined containers.

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What's new IN MATERIALS

...AT A GLANCE

INCREASED USE OF POLYETHYLENE IN OUTDOOR PRODUCTS is anticipated with the development of a new polyethylene compound that contains an ultraviolet inhibitor yet is available in natural and a range of colors. The producer says ". . . the new product will last two to four times longer outdoors than polyethylenes that contain no inhibitors to protect them from the sun." The compound is said to have good tear resistance and high impact strength. Potential uses include floats and buoys, outdoor containers, machinery covers and floor matting.

POROUS METAL CASTINGS CAN BE MADE AIRTIGHT for use at 1000 F and above by vacuum impregnating them with a newly developed mixture of zinc, copper and aluminum powders, then firing. A casting with approximately 25% porosity has an air leak rate of 510 cu in./sq in./sec before impregnation; after impregnation and aging 40 min at 1650 F it has an air leak rate of 9.9 cu in./sq in./sec. (More details next month.)

SUBSTANTIAL SAVINGS IN COSTS OF INJECTION MOLDED PARTS can be attained by using a new "valve gating" technique, according to the developer. The method holds the plastics material in a reservoir until it builds up sufficient pressure to release the valve and cause the material to gush into the mold cavity at high velocity. Large, deep plastics parts can be injection molded in relatively small machines by using multiple valve gating.

ALUMINUM FOIL CAN BE JOINED TO ALUMINUM EXTRUSIONS with what is claimed to be the first automated, continuous seam, ultrasonic welder. The producer says ". . . the machine can weld 200 in. of aluminum per min without high temperatures or high pressures." Besides aluminum, the machine can be used to join practically all metals, including refractory materials.

A NEW METHOD FOR MEASURING ADHESION OF PAINT has been developed in Britain. Disks with a spot of paint in the center are fired by compressed air down a gun barrel against a target. The target has an aperture small enough to stop the disk, but large enough to allow the spot of paint to pass through if the speed of the disk is high enough for the momentum of the paint to detach from the

surface. Knowing the weight and speed of the spot of paint, it is possible to measure its adhesive strength.

TWO ROOM TEMPERATURE CURING SILICONE RUBBERS have been developed for sealing, encapsulating, calking and glazing of electric, electronic and aircraft parts. Both are said to have good ozone, weather and flame resistance coupled with good low temperature flexibility.

LOWER COST TITANIUM PARTS are possible with a new method that extrudes titanium parts directly from cast ingots. According to a recent Air Force study, the method reduces the cost of finished titanium jet engine parts by as much as 40% compared to parts made by forging and other techniques. The extrusion process develops good mechanical properties in the materials; in all cases, these properties exceed specification requirements.

A NEW CLASS OF MAGNETIC OXIDES, structurally distinct from ferrites, has recently been discovered. Known as "rare earth-iron garnets," the materials are transparent, permitting the internal magnetic domain structure to be seen with a polarizing microscope, whereas most magnetic materials are opaque to visible light. Yttrium-iron garnet is the most completely studied of this new family.

SCALE CAN NOW BE REMOVED EASILY FROM STAINLESS STEEL and titanium alloys with a new descaling process. Metal parts are immersed in a special solution, then heat treated. The heat treatment causes a scale to form on the metal surface which can be removed quickly in an acid pickling bath.

INSPECTING ALUMINUM AND MAGNESIUM CASTINGS BY FLUOROSCOPY saves time and money, according to a recent Navy survey. The survey shows that a new type of fluoroscope detects inclusions, undercuttings and gas holes in aluminum and magnesium castings quicker and more accurately than other x-ray methods. Also the cost of fluoroscopy seems to be considerably less than the cost of other x-ray methods—16¢ compared to 80¢ in the case of one casting.

ZIRCONIUM-CLAD SEAMLESS COPPER TUBING is being produced by a newly developed technique in which two or more metals are "coextruded" through a die at high temperatures. Other combinations, available in the form of tubing, rods and special shapes, include mild steel, aluminum and molybdenum clad with stainless steel, titanium and platinum. Potential uses include chemical process and heat exchanger tubing and nuclear fuel elements.

Turn to page 143 for more "What's New in Materials"

MATERIALS BRIEFS

Easy to Get Around

A new model aluminum revolving door requires about as much effort to revolve as the effort used to pick up a knife and fork, according to the producer. Speed governors help run the door at safe operating speeds, since it rotates with only 6 to 8 oz of pressure.

Stained Safety Glass

A new process for the old art of making stained glass windows uses three layers of plastics sheeting bonded under heat and pressure between a sheet of painted glass and a sheet of unpainted glass. The result is a stained safety glass window.

Blanket for Freezers

A flexible heating blanket that uses electrically conductive rubber for a heat source instead of wires promises fast and effective defrosting of home refrigerators and freezers. The blanket, made of vinyl plastic and nitrile rubber, can reach 250 F in 3 sec.

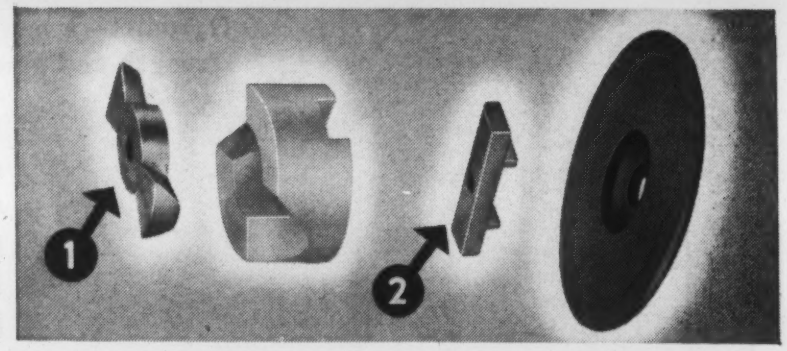
Sack Look for Skiers

Bright yellow ski suits made of vinyl film are designed especially for water skiers who want to pursue their sport in cool weather. The bright yellow color makes an easily seen marker in case the skier takes a spill.

Siphoning the Sea

A 320-ft, hump-shaped steel pipe is used to siphon salt water from the sea to ponds where it is allowed to evaporate, leaving behind deposits that are processed into household salt. The 70-ton siphon, 5 ft in dia, is fabricated from ½-in. steel plate.

MEETING DESIGN NEEDS
BRASS POWDER FORMS IMPORTANT CONNECTION FOR WESTERN ELECTRIC

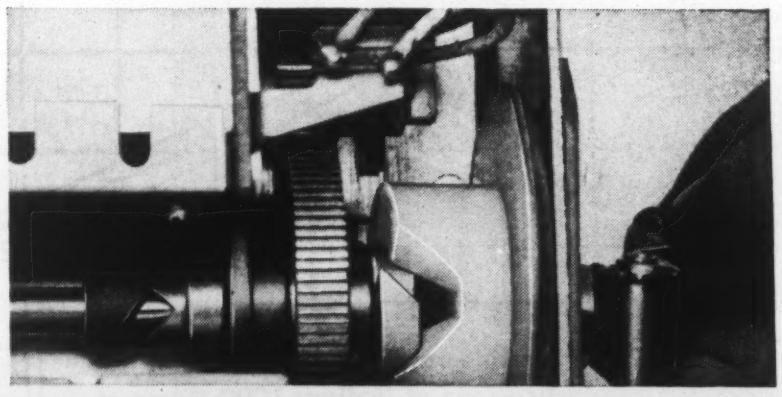


The Clutch Coupling (1) and Bar Coupling (2), shown above, function with two insulators to form an important drive linkage in Western Electric's "lineman's test set". These BRASS POWDER parts perform the dual role of activating a signaling generator and retaining a molded nylon cam that insulates the handle up to 10,000 volts.

The complex, curved surfaces on the blades of the Clutch Coupling would be very difficult and expensive to machine from bar stock. For this reason, Western Electric designed both of these parts for the powder metal process and turned the job over to an experienced fabricator*. Thus, unit cost was very low, high performance standards were met and much valuable machining time was saved.

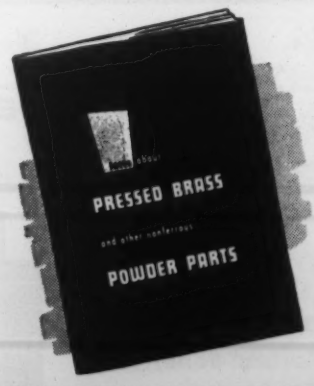
Consult with a metal powder fabricator when you have difficult design problems—or when you simply want to lower your production costs with BRASS POWDER sinterings.

*Parker White-Metal Company, Erie, Pa.



Detail of the Clutch Assembly on Western Electric's signaling generator. The Bar Coupling turns the Nylon Cam which pushes the Clutch Coupling forward to engage the drive gear.

How Can BRASS AND NICKEL SILVER POWDER PARTS Meet Your Design Needs?



For detailed information on the design, properties, production and application of brass and other nonferrous powder parts you should have a copy of our manual. It will give you 20 case histories of brass and nickel silver powder structural parts to assist in evaluating this means of production in terms of *your* particular needs.

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If your needs are not so critical as to require the advanced features of Gyromet, look into the features of Mallory 1000 —the alloy which has set today's standards for counter-balance and rotational inertia problems.

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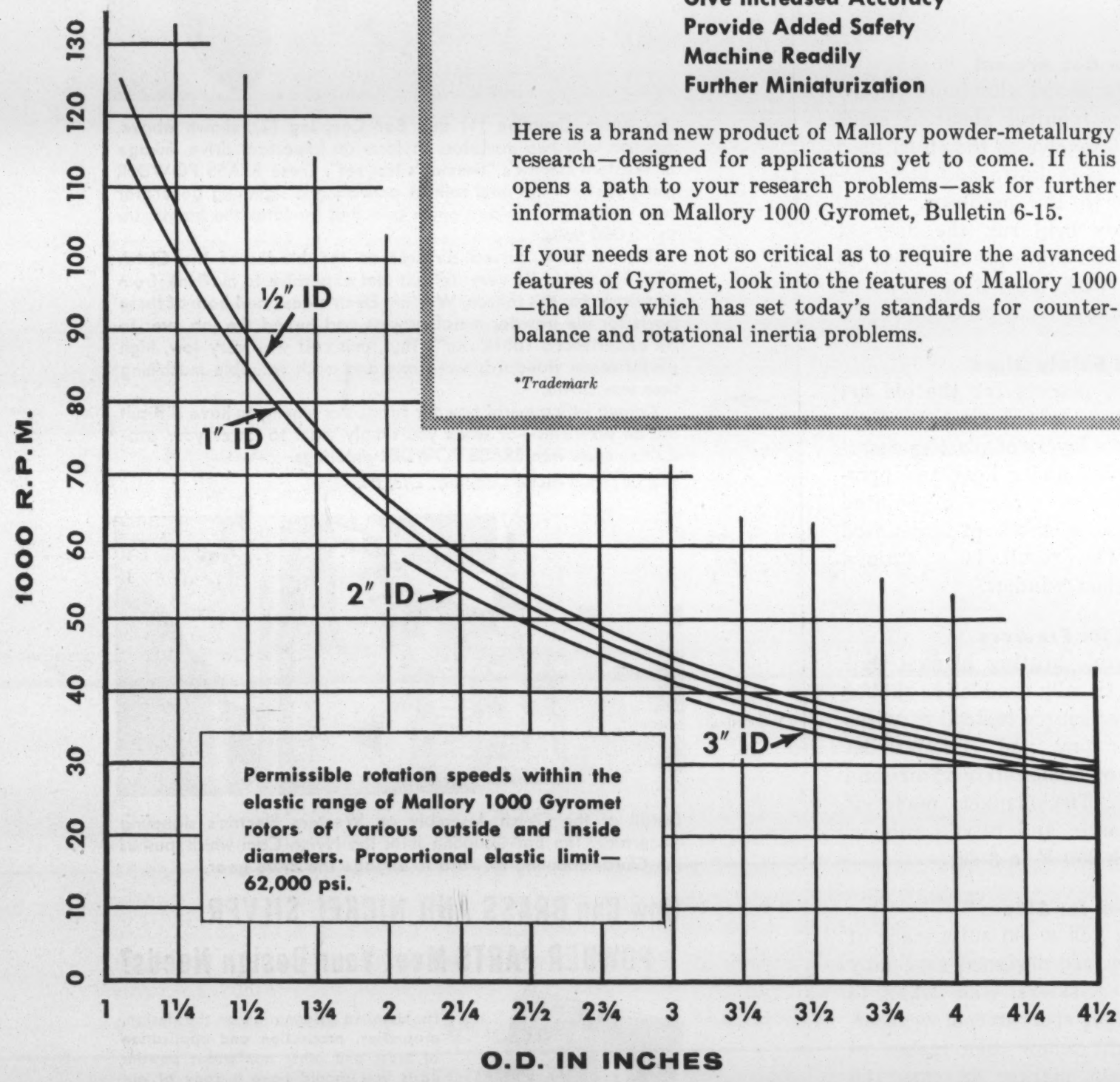

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MATERIALS AT WORK

New and interesting applications of engineering materials

Minnesota Mining & Mfg. Co.

Portable hi-fi cabinets of reinforced plastics

Reinforced plastics are now being used for cabinets of portable hi-fi phonographs and radio-phono combinations. As shown in the accompanying photos, the material is ideally suited for this application because it is extremely lightweight (only 7½ lb; see photo above), durable, and completely resistant to scratches, shock, heat, strain, moisture, scrapes and scuffs (see photo below). In addition, the material's acoustical properties have been given military acceptance.

MATERIALS AT WORK

Checker Mfg. Co.

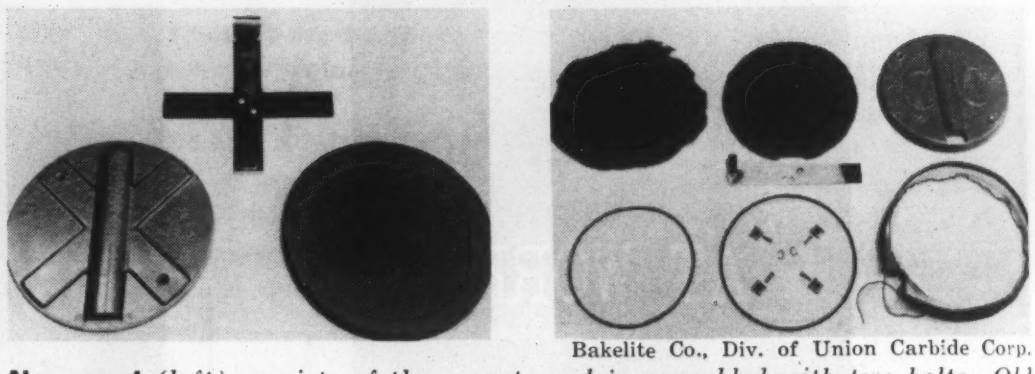
Vinyl foam cushion for taxi jump seats

The switch to molded vinyl for the taxicab jump seats shown above has not only reduced manufacturing costs and the number of parts required, but has simplified construction and resulted in greater passenger comfort and roominess.

To make the new seats, sections of vinyl foam and a nonfoaming vinyl plastisol are fused together into a single integrated covered cushion unit. This unit is then molded to any desired shape or contour.

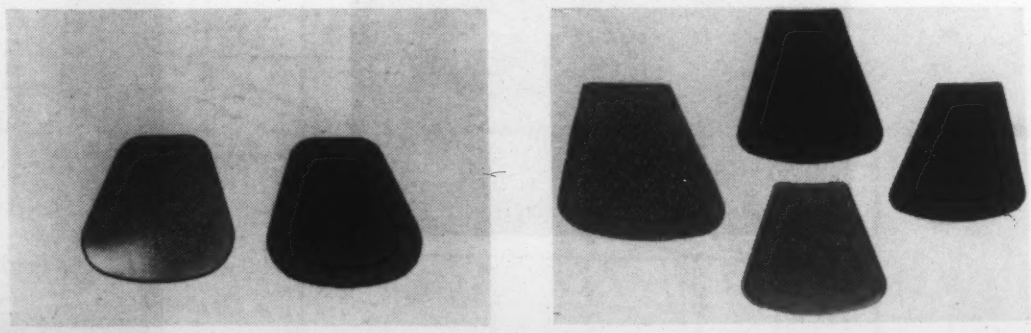
Other advantages listed for the new seats include: resistance to moisture, mildew, moths and flame; durability; ease of cleaning with ordinary soap and water; light weight; and ability to produce the cushions with varying degrees of firmness or softness.

This article is based on an entry in last year's "Best Use of Materials" Awards Competition.

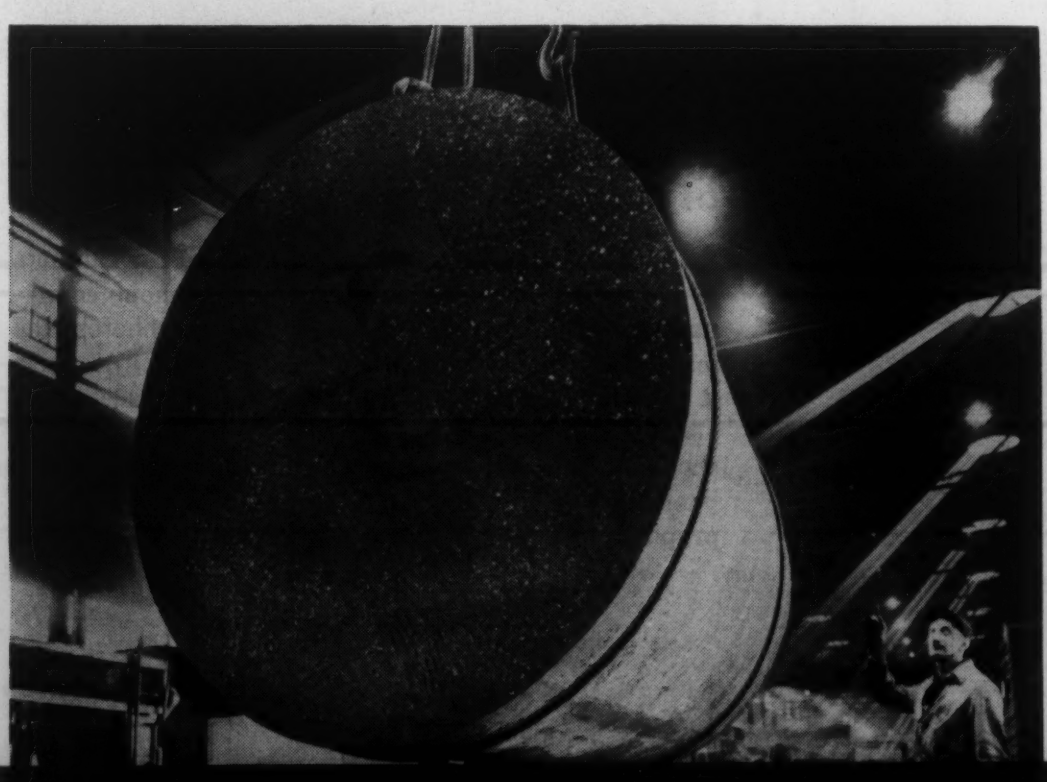


Bakelite Co., Div. of Union Carbide Corp.

New seat *(left) consists of three parts and is assembled with two bolts. Old seat (right) had seven parts and required hand assembly and sewing.*



New back *of the jump seat (left) consists of only a cushion and a frame. Previous model (right) consisted of cushion, frame and a cover for each side.*



Ten tons of carbon for largest electrode yet

Shown here is what is claimed to be the largest carbon electrode ever made: it weighs 10 tons and measures more than 5 ft in dia. According to National Carbon Co., the huge electrode was developed in anticipation of future use in mammoth submerged arc electric furnaces now being built. The large furnaces will use as much as 50,000 kva of power.

Vinyl dressing screen is electric heater

The lovely lady in the accompanying photo can obtain not only privacy but heat as well: the three panel screen she is adjusting is actually a portable electric heater which uses quilted vinyl as emitter of low frequency infrared-type rays.

Operating parts of the screen-heater are a printed aluminum foil circuit and a vinyl facing. The foil circuit is laminated to a 2-mil thick strip of Mylar which is rated at about 4000 v per mil. This laminate is backed by a low thermal conductivity panel which prevents heat from escaping through the back. The foil circuit heats the vinyl to about 70 °F above ambient room temperature, causing it to emit the infrared rays.

A major advantage of this type of heating, in addition to eye appeal, is that although the rays emitted by the vinyl facing create comfortable warmth, the screen itself never becomes hot to the touch.

Arvin Industries, Inc.

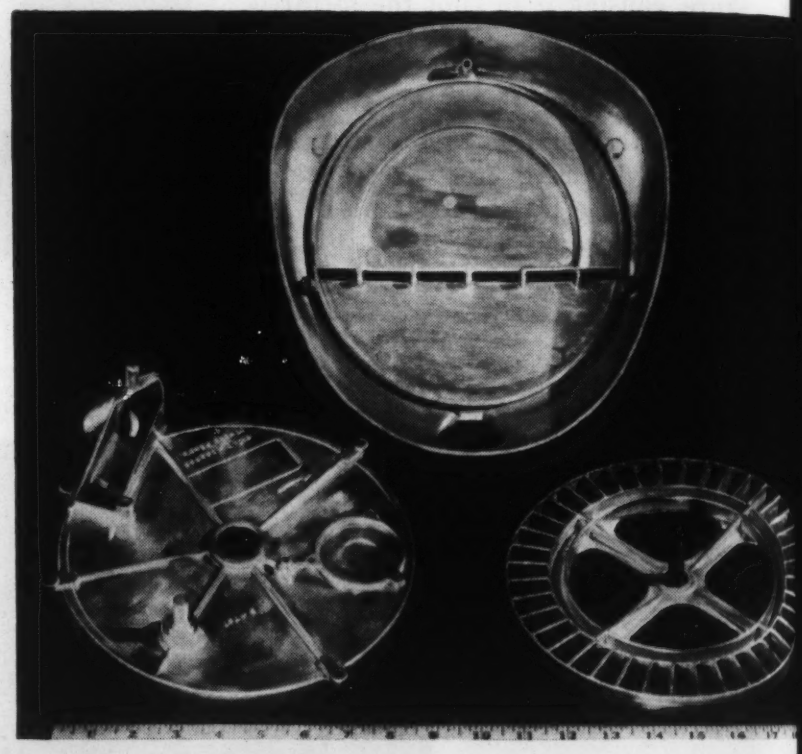
Lead, steel combine to stifle radiation

A 2-in. thick wall of lead bricks faced with steel plate will help contain radiation in Westinghouse Electric Corp.'s new materials engineering laboratory.

As shown in the photo edges of the 15-lb lead bricks are curved to eliminate flat joints through which radiation might penetrate. When the bricks are installed the wall will be covered with a layer of ¼-in. thick steel plate, followed by 16 in. of steel shot, and then with more ¼-in. steel plate.

All photos American Die Casting Institute

VACUUM CLEANER



FLOOR POLISHER

Six aluminum die castings simplify design of cleaner

Six aluminum die castings figure prominently in the design of a new home cleaning and polishing system. The system, composed of a separate vacuum cleaner and floor polisher, uses power from the cleaner to run both units: a flexible hose is merely transferred from the suction port to the blower port and attached to the polisher.

Each of the two units consists of three aluminum die castings. The floor polisher, composed of an upper housing, chassis and turbine, weighs only 8 lb. The turbine casting, which is geared to two brushes in the polisher assembly, incorporates a steel center post cast as an insert. The castings are painted and assembled as cast.

The aluminum die castings in the cleaner, consisting of upper and lower housings and cover, require one operation before painting and assembly: the eight louver openings in each side of the upper housing have to be pierced. Although the louver could have been cored during

(continued on p 184)

MORE MATERIALS AT WORK

Honeycomb absorbs shock..184
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New Economy and Speed in Tooling Production for the Airframe Manufacturer with POLYTOOL

Photos courtesy of Arrowsmith Plastic Tooling, Inc., Los Angeles, Calif.

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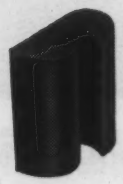

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Malleable iron for gears

To the Editor:

I have just scanned through Manual No. 143, "Materials for Gears," in the November issue of MATERIALS IN DESIGN ENGINEERING.

I would appreciate having your reasons for the complete omission in Mr. Woldman's article of any mention of malleable and pearlitic malleable irons, both of which have been utilized very effectively for gears for countless years, as is widely recognized by experienced design engineers.

GORDON B. MANNWEILER
Research Engineer
Eastern Malleable Iron Co.
Naugatuck, Conn.

To the Editor:

Both malleable iron and pearlitic malleable iron are used extensively for gearing of all sizes in many applications. They are manufactured under ASTM specifications, SAE specifications and also under the manufacturers' own proprietary names and specifications. The omission of any references to these irons was a serious error on my part.

I would recommend that an addendum to my gearing article be published in a subsequent issue to cover malleable and pearlitic malleable iron gearing.

NORMAN E. WOLDMAN
Consulting Engineer
Upper Montclair, N. J.

Measuring diamond hardness

To the Editor:

In the Nov '57 issue of MATERIALS IN DESIGN ENGINEERING, page 3, a reference is made to man-made industrial diamonds. It states that synthetic diamonds would be equivalent in hardness to natural diamonds. I have never been able to learn how the hardness of diamonds is measured.

R. D. FABER
International Nickel Co., Inc.
New York, N. Y.

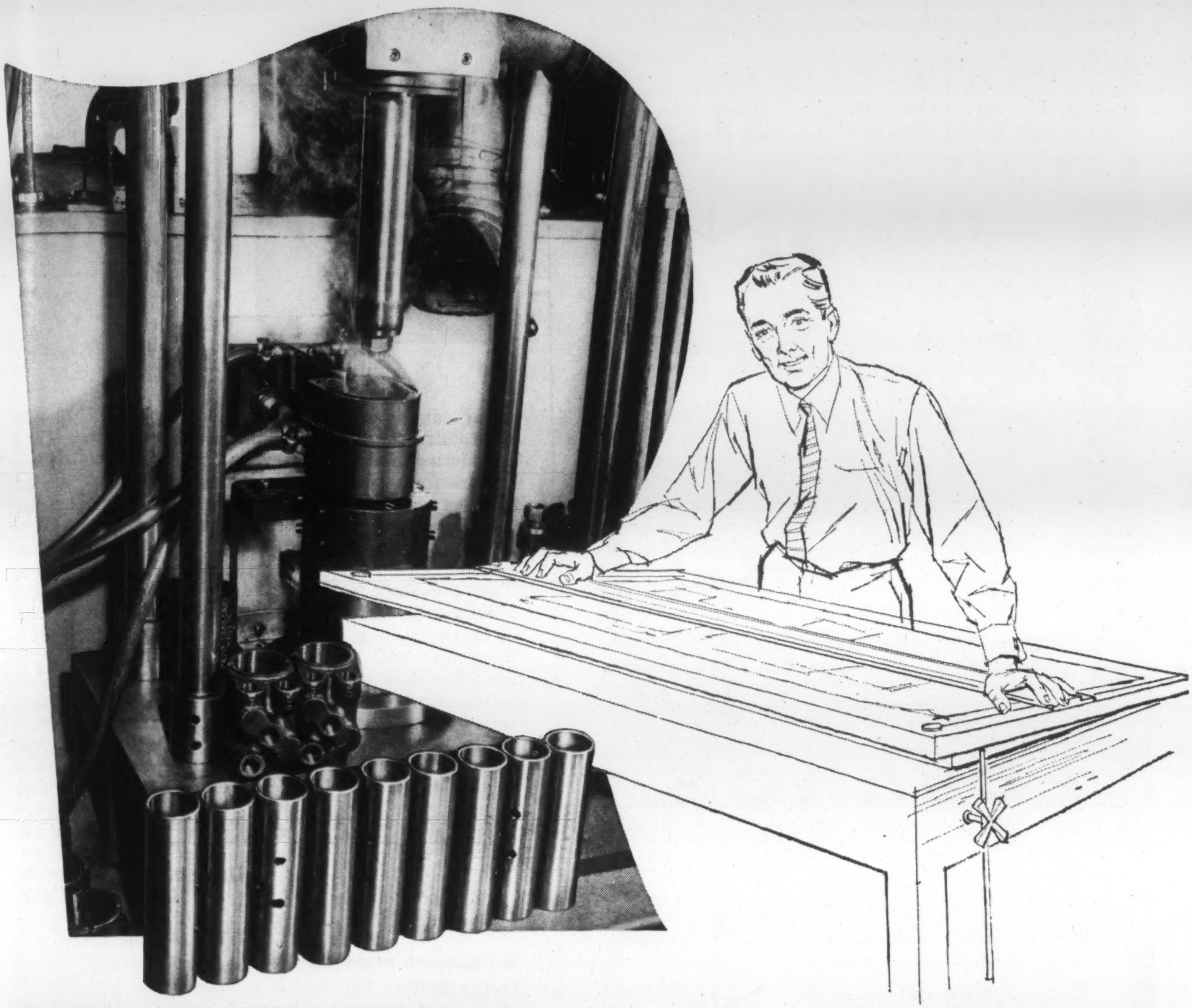
Strictly speaking, it isn't. All hardness values are relative, and diamonds have been assigned the top value of 10 on the Moh scale.

More on joining enameled parts

To the Editor:

I will bring you up to date on the progress made in solving our problem of joining lips coated with porcelain enamel and subject to radiation from a gaseous electrical discharge in vacuo (see my letter, Oct '57 issue, p 14).

We have been investigating the ceramic struc-



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For more information, turn to Reader Service card, circle No. 474

tural adhesives—Corning's "solder glass" 7570 and Consolidated Electrodynamic's "Ceramicite" — and conducting literature surveys on the inorganic elastomers for several months. At present there are no data available on the inorganic elastomers from the Air Force or its agencies, or from the Dept. of Commerce. The severe outgassing in vacuo of "Saureisen" cements precludes their use in these joints. Two porcelain enameled, double-walled, hemicycle, axially-split, half cylinders, made by forming pieces of copper tubing into themselves and holding a uniform wall-wall separation of approximately 3/8 in. and edge radii of 3/16 in., have been bonded together satisfactorily with the ceramic structural adhesive technique. The two ceramic structural adhesive joints, in a plane containing the cylindrical axis, are dielectric, electrically nonconductive, and probably vacuum-tight. The last feature has not been verified as yet.

S. E. OPENSHAW
Mechanical Designer
University of California
Livermore, Calif.

Manganese alloy family

To the Editor:

I read your recent article, "Three Manganese Alloys," with a great deal of interest. Another member of the manganese alloy family worthy of your attention is the 60 copper-20 nickel-20% manganese alloy, known commercially as C.D.C. 720 (Chicago Development Co.).

I have been working with this alloy for the past few years and have found it to be a very attractive structural material for nonmagnetic applications. It is an age hardening alloy capable of developing high strengths.

HAROLD BERNSTEIN
Engineering Dept.
U. S. Naval Gun Factory
Washington, D. C.

This alloy was not included because the manganese content is less than 50%. However, an article on this alloy will appear in the near future.

Gas-filled sealing rings

To the Editor:

Are you familiar with the firm which, we understand, has developed gas-filled steel rings which may be used to seal pump shafts and similar equipment? With increased temperature the gas which is enclosed in the rings expands and provides a tight seal.

N. ORDJANIAN
Columbia Technical Corp.
Woodside, N. Y.

Gas-filled stainless steel o-rings are produced by Advanced Products Co., North Haven, Conn.

ONE POINT OF VIEW

Next month: the Design Show

Next month during the week of April 13th the third annual Design Engineering Show and Conference will be held in the International Amphitheatre in Chicago. As in other years, we strongly recommend that you plan to attend. It is the one and only show and conference that is devoted exclusively to the interests and problems of product planners, designers and engineers. It offers an excellent opportunity to get a comprehensive look at the latest developments in engineering materials, finishes, parts and components that are used by the manufacturing industries.

It's still growing

Since its inception in 1956 the show has grown rapidly. This year there will be more than 400 exhibits occupying four times more floor space than in the first show. This rapid growth reflects the wide acceptance of the Design Show as a useful and successful industrial exposition.

Materials have big part

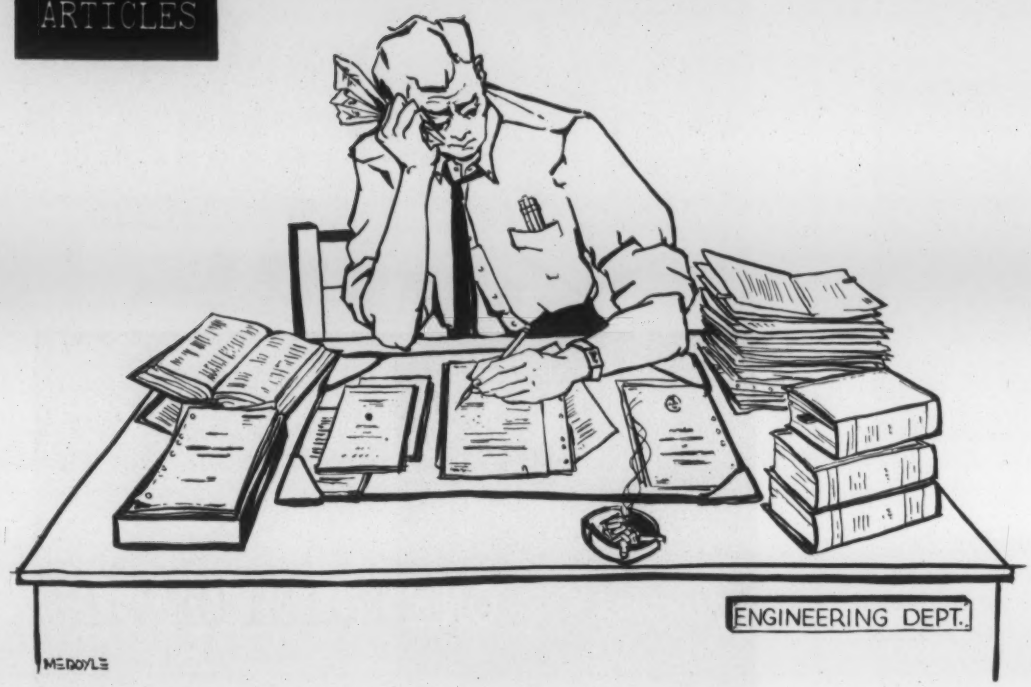
About 40% of the exhibits will display materials, material forms, and finishes. We, as the materials magazine of the design engineering field, are naturally happy to see such a large proportion of the show devoted to materials. Our own booth (No. 602) will feature the parts and products that won the top awards in our second annual Awards Competition for Best Use of Materials in Product Design. The winning entries this year demonstrate unusual and imaginative use of materials in the design of industrial and consumer products. The award winners will be honored at a special awards dinner to be held during Design Show week.

The Design Engineering Conference, held in conjunction with the show, will again be sponsored by the Machine Design Div. of the American Society of Mechanical Engineers. Like the show, the conference has grown rapidly both in attendance and the number of papers presented. Of special interest to most you will be the two sessions on engineering materials. The papers will include a survey of honeycomb sandwich materials, the latest information on the uncommon metals, important data on the impact resistance of plastics, and useful information on the compatibility of many different materials in bearing contact. Another session will suggest solutions to the serious and growing problem of finding the right technical information at the right time.

You will benefit

So, if you have anything to do with selecting materials and designing products, we believe you will benefit by attending the Design Engineering Show and Conference.

FEATURE ARTICLES



■ Standards of quality and performance for materials are an indispensable part of the product manufacturing industries. Today thousands of engineering materials standards and specifications are being used. They are issued by many technical organizations and are scattered throughout many documents. To use them effectively, it is important for engineers and designers to know what kind of standards and specifications are available, how they are developed, what they cover, and how they are identified.

This article is devoted to a discussion of the organizations that issue national standards and specifications on many different engineering materials.

Confused? Here is a . . .

Guide to Materials Standards & Specifications

Part 1—Government and National Standards

by S. P. Kaidanovsky,
Consulting Engineer

What Are Standards and Specifications?

These two words are often used interchangeably to refer to procurement documents, standard test methods, performance requirements, recommended practices, definitions, glossaries and simplification lists. Specifications that are used repeatedly and have become widely accepted are often referred to as standard specifications, or briefly, standards.

Two terms defined

The dictionary defines a *standard* as "any measure of extent, quality, or value established by law or by general usage or consent . . ." and a *specification* as "a written statement containing a minute description or enumeration of particulars." A positive distinction is also made by the Government between a standard and a specification. A specification is a purchase document that contains 1) a clear, accurate description of the technical requirements for a product, material, or service; 2) the procedure used to determine that the requirements have been met; and 3) the packaging requirements. A standard is a document that establishes engineering and technical limitations and applications for products, materials, processes, methods, designs, and engineering practices.

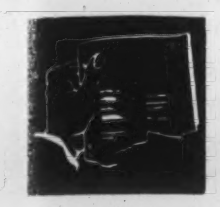
Three types of standards

Standards and specifications may be classified as national standards, industry standards, and company standards:

National standards are those which apply to a wide variety of industries and range of materials and products. They are issued by such organizations as the American Standards Assn., American Society for Testing Materials, Underwriters Laboratories and the Government. Because of their wide applicability their requirements are general.

Industry standards are issued by organizations performing a standardizing activity in specialized fields. They are issued by such organizations as the American Society of Mechanical Engineers and the American Institute of Electrical Engineers. They are limited in scope, and their requirements are more detailed than those of national standards.

Company standards are issued by users of materials and products. Their requirements are still more specific and detailed, reflecting the particular needs of the individual company. Company standards frequently are based upon, or refer to, national and industry standards.



Federal specifications and standards

Three major classes of specifications and standards are developed by the Federal Supply Service of the General Services Administration. They are known as Federal Specifications, Interim Federal Specifications, and Federal Standards. They cover all materials and supplies purchased by the civilian branches of the Government and by the military agencies when appropriate.

The present method of developing the specifications and standards is the so-called "assigned agency method." A project is assigned to the agency, civil or military, having the greatest concern and the requisite technical staff. The Standards Div. of the Federal Supply Service follows the progress of the assignments and assists in the coordination with other agencies. It also handles a number of projects itself.

Federal Specifications . . .
cover materials, products and services used by two or more Federal agencies, at least one of which is a civil agency. They can also cover new items of potential general application. Federal Specifications are coordinated, circulated for comments, and approved for use by all interested Government agencies, including the military.

Federal Specifications are designated by a symbol and number composed of three parts. For example, the specification, "Aluminum Base Alloys; Sand Castings," is designated QQ-A-601a, where:

QQ—group of procurement (Metals) to which specification relates

A—first letter of first word (Aluminum) in title of specification

601—basic serial number determined by alphabetical location

a—suffix letter to the basic number, indicating first revision. Subsequent revisions designated by letters *b*, *c*, etc.

Minor changes in the specifications are made by amendment, indicated by figures *1*, *2*, etc., and placed below the specification designation. The date of issue or the date of revision or amendment is given in each document.

Interim Federal Specifications . . .
are developed and issued by an individual Government agency to satisfy an immediate need. Their use is optional for other Federal agencies. Interim Federal Specifications are intended for final processing as regular, coordinated Federal Specifications.

Interim Federal Specifications are designated in the same manner as Federal Specifications with two exceptions:

1. Two zeros precede the basic serial number.

2. Following in parentheses is a code designating a) the agency responsible for the development and maintenance of the specification, called the "assigned agency"; and b) the activity within the agency responsible for the actual development and preparation of the specification, called the "preparing activity."

For example, the designation of the Interim Federal Specification, "Steel, Carbon: Sheet and Strip," is QQ-S-00640 (Army-Ord). The Dept. of the Army is the assigned agency, and the Ordnance Corps is the preparing activity.

Federal Standards . . .
are of three types:

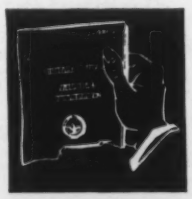
1. Supply item limitation standards that limit procurement to the qualities, types, and sizes of materials and products most economically and effectively satisfying the needs of Government agencies.

2. Test methods standards to bring about agreement between Government, suppliers and industrial users on standard test methods for uniform use.

3. Engineering and process standards, such as glossaries, and guides for preparation of "item descriptions" for cataloging of materials and products.

Interim Federal Standards, like Interim Federal Specifications, are developed and issued by an individual Government agency for its own immediate use. They are optional for other agencies.

Federal Standards are designated numerically. For example, the standard, "Steel; Chemical Composition and Hardening," is designated Fed. Std. No. 66. In designating Interim Federal Standards, both the assigned agency and the preparing activity are indicated, as in Interim Federal Specifications. The date of issue, revision or amendment is given in each document.



Military specifications and standards

The specifications and standards developed by the military departments cover materials, products and services purchased by the military branches of the Government, and by other Federal agencies when appropriate.

The present method of developing Military Specifications and Military Standards is to assign a project to an interested military department having the requisite technical staff. The Standardization Div., Office of the Secretary of Defense, Supply and Logistics, is responsible for the direction of

the standardization program of the military departments in the Dept. of Defense.

Military Specifications . . . consist of *coordinated* specifications and *limited coordination* specifications. Coordinated specifications, formerly known as Joint Army-Navy Specifications (JAN), cover items of common use. They are developed by the cooperative effort of all interested activities (bureaus, corps, services) in the Army, Navy and Air Force departments. Limited coordination specifications are purchase specifications of a single military department interest, or those prepared by a military department or activity to satisfy an immediate procurement need.

The coordinated specifications are designated by a symbol and number. For example, MIL-P-798B is the specification, "Plastic Materials, Laminated, Thermosetting Rods, and Tubes," where:

MIL—abbreviation for MILITARY
P—first letter of first word (Plastic) in title of specification
798—basic serial number
B—suffix letter to basic serial number, indicating second revision

Minor changes are made in coordinated specifications by amendment, indicated by figures *1, 2,* etc., and placed below the specification designation. The date of issue, revision or amendment of a specification is placed under the symbol and number.

Limited coordination specifications are also prefixed by the letters *MIL,* but in addition are identified by a suffix (in parentheses) to the basic symbol and serial number. For example, the specification, "Iron, Malleable, Pearlitic, Castings," is designated by MIL-I-11444(Ord). The suffix (*Ord*) identifies the activity (Army Ordnance Corps) issuing the specification.

Following is a list of suffixes for the identification of limited coordination specifications:

Army

CmlC—Chemical Corps
CE—Corps of Engineers
Med—Army Medical Service
Ord—Ordnance Corps
QMC—Quartermaster Corps
SigC—Signal Corps
TC—Transportation Corps

Navy

NAVY—Dept. of the Navy
MC—Marine Corps
AER—Bureau of Aeronautics
BuMed—Bureau of Medicine and Surgery
NOrd—Bureau of Ordnance
Pers—Bureau of Personnel
Ships—Bureau of Ships
S&A—Bureau of Supplies and Accounts
Docks—Bureau of Yards and Docks

Air Force

USAF—Dept. of the Air Force
ASG—Aeronautical Standards Group

Military Standards . . . are limitations applying to items, materials, processes, methods, designs and engineering practices. They are issued in two formats: 1) book form standards, and 2) sheet form standards. Book form standards cover engineering practices, charts, categories of dimensional and functional details, graphs, formulas and lists. Sheet form standards cover physical items and design features. Military Standards, like Military Specifications, are divided into coordinated standards and limited coordination standards.

Book form standards are designated by the symbol *MIL-STD,* followed by Arabic numerals as assigned to the standard. For example, MIL-STD 184 is the Military Standard, "Identification Marking of Aluminum, Magnesium and Titanium." Sheet form standards are designated by the symbol *MS* followed by Arabic numerals as assigned to the standard. For example, MS15467 (Ships) is the Military Standard, "Resinous Material, Formula No. 95." The suffixes for the identification of activities issuing limited coordination standards are the same as for the identification of limited coordination specifications.

Commercial standards, simplified practices

Unlike Federal Specifications, which must be used in procurement by all Federal agencies, Commercial Standards and Simplified Practice Recommendations are voluntary and are developed for industrial or trade use. They are developed through cooperative action of producers, distributors, testing laboratories and users, and are coordinated and published by the Commodity Standards Div., Office of Technical Services, Dept. of Commerce.

Commercial Standards . . . cover terminology, types, classification, grades, sizes, methods of tests and use characteristics of materials and products. They serve to establish clear understanding between buyers and sellers, and provide uniform bases for fair competition.

Commercial Standards are identified by the letters *CS,* followed by a serial number and the year of issue, or in the case of revision, the year of the last revision. For example, Commercial Standard, "Rigid Polyvinyl Chloride Sheets," dated 1955, is designated by CS201-55, where *201* is a serial number.

Simplified Practice Recommendations . . . designate certain sizes, varieties, and types and grades of materials as being approved for regular stock purposes, after superfluous variety has been eliminated.

Simplified Practice Recommendations are identified by the letter *R,* followed by a serial number and the year of issue, or in the

case of revision, the year of the last revision. For example, Simplified Practice Recommendation, "Copper and Copper-Alloy Rod," dated 1950, is designated R241-50, where *241* is the serial number.

ASTM standards

The American Society for Testing Materials is a leading organization in the field of materials standards, and its standards are used widely in industry. ASTM Standards comprise specifications, methods of testing, recommended practices, definitions of terms, charts and tables. Such documents, when designated as standards, are those formally adopted by the Society. Prior to adoption as standards they are published as "Tentatives" and represent the latest thoughts and practice on the subject covered.

Every ASTM Standard is evolved by a committee of specialists in the particular field of activity. The membership of the committee is divided about equally among persons identified with user interests, producer interests, and general interests (neutral). The Society in its standardization activities thus capitalizes upon the inherent diversity of interest between user and producer.

The designation of ASTM Standards consists of three components: a letter prefix indicating the type of material or nature of the standard, followed by the number of the standard, and a final number indicating the year of the issue or adoption, or in the case of revision, the year of the last revision. The letter and number which designate the standard are permanent.

The following prefixes are used in ASTM Standards:

A—Ferrous Metals
B—Nonferrous Metals
C—Cementatious, Ceramic, Concrete and Masonry Materials
D—Miscellaneous Materials
E—General Testing Methods and Definitions
F—Materials for Specific Applications

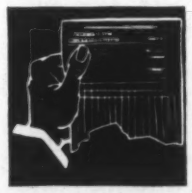
For example, specification, "Manganese-Molybdenum Steel Plates," issued in 1956, is designated A302-56, where *A* refers to ferrous metals.

Prefixes used in ASTM Standards are also used in Tentatives. Tentatives are designated by the inclusion of the letter *T* at the end of the designation. For example, the designation of the specification, "Cold-Rolled Carbon Steel Sheet, Commercial Quality (Tentative)," is A366-53T.

About This Series

The aim of this series of six articles is to bring together in one place useful information about the many materials standards and specifications documents available to the engineer and designer. The articles will be confined mainly to standards and specifications on materials and materials forms, and will not cover materials testing standards, "end product" standards, or standards chiefly concerned with sizes or tolerances.

The remaining five articles in the series will deal with organizations and standards on the following specific groups of materials: irons and steels, nonferrous metals, plastics and elastomers, other nonmetallics, and finishes. Included in each of the articles will be summary lists of and references to all important standards and specifications.



SAE standards

The standards work of the Society of Automotive Engineers covers standards, recommended practices, and general information reports on materials, finishes, parts and fittings, and equipment. The standards work of the SAE is carried on by a number of committees. All technical reports, including standards approved and practices recommended, are advisory only.

The SAE plays an important part in aeronautical standardization. Its standards cover materials and processes, as well as assemblies, components and parts.

SAE Standards and SAE Recommended Practices . . .
were developed primarily for the automotive field, but are widely used in many other industrial fields. SAE Standards are based on sound, established engineering practice. SAE Recommended Practices are based on sound engineering principles and are intended as guides toward standard engineering practice. Use of SAE Standards or SAE Recommended Practices is entirely voluntary.

Aeronautical Materials Specifications . . .
are material and process specifications conforming to sound, established engineering and metallurgical practices in the aircraft industry. They are given numbers prefixed by *AMS*.

Aeronautical Standards . . .
are of three types: 1) design standards conforming with sound, established engineering practices in the aircraft industry; 2) parts standards conforming with engineering practices in the engine, propeller, accessory equipment and airline industries; or 3) other aeronautical specifications that do not fall within the category of AMS. They are given numbers prefixed by *AS*.

Aeronautical Recommended Practices . . .
are dimensional designs or performance recommendations based on sound engineering principles and are intended as guides toward standard engineering practice. They are given numbers prefixed by *ARP*.

Aeronautical Information Reports . . .
contain engineering data that are of sufficient value to warrant publication, but which do not lend themselves to the classification of standards or recommended practices. They are given numbers prefixed by *AIR*.

American standards

The American Standards Assn. is a federation of trade associations, and technical and professional societies, serving as a clearing house for standards.

An American Standard is a standard of national application approved by the ASA as having been accepted by all groups and organizations substantially concerned with its scope and provisions. The types of standards and specifications covered in this article can be approved as American Standards. American Standards are optional for use by industry. However, American Standards are sometimes adopted by a Government agency or other organizations for mandatory use.

American Standards come into existence through three basic methods. All three operate on the underlying principle that there must be a consensus of all interested parties:

1. Sectional committee method—A committee, consisting of all groups and organizations substantially concerned with the scope of a standards project, formulates or revises a standard or a group of standards. The sectional committee may delegate the technical work to subcommittees, especially if several standards are being developed under one project.

2. Existing standards method—This method makes it possible under certain conditions for existing standards of any organization to be submitted to ASA for approval without going through any of the other channels for developing American Standards. The American Society for Testing Materials is foremost among the organizations that have many of their own standards recognized as American Standards. An American Standard approved under the existing standards method will not lose its original identity. It will continue to carry the title and the designation assigned by the originating organization, in addition to its ASA designation and its universal decimal classification (UDC) for international, as well as domestic, bibliographic purposes.

3. General acceptance method—This method is for simple projects. Under this method, standards are discussed and agreed upon only at a general conference. No continuing committees are formed; however, an *ad hoc* committee may make minor editorial changes.

The designation of an American Standard consists of three component parts: 1) project letter of the field under which the standard is classified (e.g., C for Electrical Engineering); 2) followed by a number designating a group of materials (e.g., C7 for Bare Wire) and a decimal (e.g., C7.2 is medium-hard-drawn copper wire); 3) and the year of issue or of the latest revision of the standard. For example, "Medium-Hard-Drawn Copper Wire, Specifications for," is designated C7.2-1953 (ASTM B2-52), since it is an ASTM Standard approved by ASA.

Indexes to National Standards and Specifications

Federal—Index issued annually; cumulative supplements are sold on subscription basis by Supt. of Documents, U. S. Government Printing Office, Washington 25, D. C.

Military—Index consists of four volumes: Vol I, Munitions Board Standards Agency (out of print); Vol II, Dept. of the Army; Vol III, Dept. of the Navy; Vol IV, Dept. of the Air Force. Each volume published semi-annually on Apr 1 and Oct 1. Cumulative supplements published in the interval between each semi-annual volume. Sold on subscription basis by Supt. of Documents, U. S. Government Printing Office, Washington 25, D. C.

Commercial—Catalog No. 978, Classified List of Commercial Standards, and Catalog No. 979, Alphabetical List of Simplified Practice Recommendations, with prices, available from Commodity Standards Div., Office of Technical Services, U. S. Dept. of Commerce, Washington 25, D. C.

ASTM—Index, published annually, lists alphabetically and in numeric sequence ASTM Standards and Tentatives. Available from American Society for Testing Materials, 1916 Race St., Philadelphia, Pa.

SAE—SAE Standards and Recommended Practices are embodied in the *SAE Handbook*, published annually. Indexes of Aeronautical Materials Specifications, Aeronautical Standards, Recommended Practices and Information Reports available from Society of Automotive Engineers, 485 Lexington Ave., New York 17, N. Y.

American—Index and price list available from American Standards Assn., 70 E. 45th St., New York 17, N. Y.

by **M. J. Sanger, G. T. Gmitter, E. M. Maxey,** *Central Research Laboratories, General Tire and Rubber Co.*

Until the polyether types were developed, urethane foams appeared to have important limitations as cushioning materials. This article tells . . .

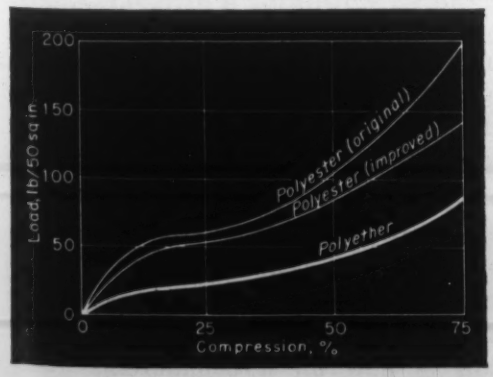
Cushioning *characteristics of polyether foams make them well suited for use in furniture.*

How Polyether Foams Compare

with other flexible urethane foams in . . .

■ Major benefits offered by urethane foams of the polyether type, in comparison with the adipic polyester types, (adipate foams), are 1) a relatively smooth loading curve, greatly reducing the plateau effect common to the adipic polyester types, 2) high resilience, or rebound, and 3) a relatively high degree of resistance to humidity aging and to chemicals. This combination of properties provides excellent cushioning characteristics. On the other hand, adipate foams have a higher hysteresis (or energy loss) than the polyether types and thus are more suitable for shock absorption applications.

Data are presented here for a commercially available polyether foam in comparison with both original and improved polyester types (see box on next page).



Load-deflection *curves for polyester and polyether foams.*

1. Physical properties

Compression-deflection, hysteresis and resilience—Loading curves for the three different foams are shown in the accompanying graph. Both polyester foams show a high initial stiffness followed by a plateau effect. Polyether foam shows a more gradual rise in the initial deflection range and a less pronounced plateau in the remainder of the curve.

Resilience and hysteresis values for typical foams of these three types are shown in Table 1. Polyether foam, in comparison with adipic polyester types, has a

TABLE 1—MECHANICAL PROPERTIES

Material ➡	Polyether[a] Foam	Adipic Polyester Foam (improved)	Adipic Polyester Foam (original)
Density, lb/cu ft	2.2	2.2	2.2
Rebound, %			
Schopper	35-45	25-35	20-30
Lupke	45-55	35-45	30-40
Hysteresis, %[b]	36	52	53
Tensile Strength, psi	18-24	20-30	16-20
Tear Strength, psi	3-5	4-6	3-5
Elongation, %	250-400	200-300	150-250
Compression Set, % of defl[c]	5-15	6-18	6-18
Density, lb/cu ft	2.5	2.8	2.8
Flex Resistance[d]			
Change in Height, %	−1.5	−6.0	−2.4
Change in Indentation-Load, %	−25.9	−38	−40
Low Temp Flexibility, % loss in flex[c]			
−20 F	55	77	70
−40 F	80	93	93

[a] Polyfoam.

[b] Hysteresis values are calculated from the loading and unloading curves by the following formula:

$$\text{Hysteresis} = \frac{\text{(area under loading curve—area under unloading curve)}}{\text{area under loading curve}} \times 100.$$

[c] ASTM D1055-54T.

[d] RMA standard flexing test; 250,000 flex cycles.

TABLE 2—THERMAL CONDUCTIVITY[a]

Material[b] ↓	Avg Mean Temp, F	K Value, Btu/hr/sq ft/°F/in.
Polyether Foam		
(2.5)	75	0.27
	40	0.24
Adipic Polyester Foam (improved,		
2.8)	75	0.28
	40	0.26
Polystyrene Foam		
(closed cell 2.2)	32	0.24
Rock Wool (6.0)	70	0.26
Glass Wool (4.0)	70	0.29
Compressed Cellulose (13.2)	70	0.34
Cork (8.0)	68	0.26

[a]ASTM C177-45, Guarded Hot Plate Method.
[b]Density in lb per cu ft given in parenthesis.

TABLE 3—ACOUSTICAL PROPERTIES[a]

Material ↓	Sound Absorption Coefficient 125 Cps	250 Cps	500 Cps	1000 Cps	2000 Cps	Noise Red. Coef[b]
Polyether Foam	**0.21**	**0.28**	**0.40**	**0.56**	**0.70**	**0.49**
Adipic Polyester Foam (improved)	0.16	0.21	0.38	0.41	0.48	0.37
Latex Foam (med density)	0.24	0.21	0.24	0.21	0.41	0.26
Compressed Cellulose						
Plain	0.19	0.35	0.65	0.24	0.24	0.33
Perforated	0.25	0.62	0.71	0.76	0.70	0.70
Glass Fiber Mat	0.08	0.13	0.52	0.64	0.56	0.46

[a]Impedance tube method. High value indicates high sound absorption. Values are for 1-in. thick material.
[b]Average of coefficients at 250-2000 cps.

marked reduction in energy loss and improved resilience, or rebound. These characteristics represent an improvement in the properties of a foam for many cushioning uses. Polyether foam also retains its resilience after flexing, as contrasted with a loss in resilience for original polyester foam. Resilience values shown in Table 1 may be somewhat lower than those obtainable from foams based on polytetramethylene ether glycol.

Strength and set—Table 1 also compares tensile and tear strength, elongation and compression set characteristics of the three types of foam. Although polyether foam does not exhibit the extremely high tensile strength values provided by some formulations of improved adipate foams, it is adequate in both tensile and tear strength. It shows a definite increase in elongation over both polyester foams. Polyether foams have relatively low compression set values; extremely low values have been obtained on selected formulations.

Flex resistance—Results of flexing tests carried out according to the standard RMA (Rubber Manufacturers' Assn.) method indicate no breakdown and only minor reductions in height after 250,000 cycles of compression to 50% at a

The Polyethers: Newest of the Urethanes

Urethane foams are expanded plastics materials formed by reacting diisocyanates with resinous polymers (see MATERIALS & METHODS, June '56, p 143). The original flexible urethane foams were adipic polyester-isocyanates, first introduced commercially in this country in 1954. Early foams had definite limitations, such as a harsh boardy feel caused by the high modulus at low deflections; low resilience at both normal and low temperatures; and, in some cases, unsatisfactory resistance to humidity aging.

Adipic and dimer polyesters

Improvements in adipic polyester-isocyanate urethane foams have produced materials with higher resilience and improved loading curves. However, the extreme plateau effect in the compression-deflection curve still persists, making the materials unsatisfactory for many cushioning applications.

One recent and promising approach to improving polyester-type urethanes is the use of dimer acid polyesters. Foams produced with these resins have good resistance to humidity aging and also possess a fairly good loading curve. Since it is too soon for a complete evaluation of these materials they are not included in the comparisons given in this article.

The nature of polyethers

The polyether approach to providing acceptable cushioning materials consists of creating a new backbone polymer based on polyether glycols. In such foams the ether linkage replaces the ester linkage.

Polyether foams can be produced from a wide variety of glycol ethers as starting materials; thus several different types of polyether urethane foams have been developed based on polytetramethylene ether glycol, modified ether glycols such as Pluronics or Tetronics, and polypropylene glycols.

Some problems arise

Polyester-type urethane foams can be produced by either the one shot, three-component system, or the prepolymer system. Polyether types, because of the slow reaction between polyether glycols and isocyanates, utilize the two-stage prepolymer system. A prepolymer is first made by reacting the polymeric glycol with an isocyanate. This prepolymer is mixed with the activator at the foaming machine.

This type of processing raises the problem of modifying mixing equipment without sacrificing efficiency. Solution of such problems as controlling size and uniformity of cells and maintaining optimum curing conditions has also required concentrated effort. In spite of these problems production of polyether foam is now on a commercial scale.

rate of 60 cpm (Table 1).

Low temperature flexibility of the early adipate foams was generally not good enough to permit their use for outdoor cushioning in cold weather. Polyether foams show much greater flexibility at low temperatures than do the adipate foams.

Thermal and acoustical insulating properties — Results of thermal conductivity tests are shown in Table 2. Conductivity values for other thermal insulating materials are included for comparison. The polyester and polyether foams appear to be approximately equivalent and compare favorably with other insulating materials.

Sound absorption coefficients for polyester and polyether foams are shown in Table 3. Values for several commercial acoustical materials are also presented for comparison. Polyether foam appears to be somewhat better than polyester foam in absorption of sound; at high frequencies it is equivalent to perforated cellulose.

2. Chemical properties

Chemical resistance—Polyether foam's superior resistance to solvents, oils and other chemicals is shown in Table 4. Although this superiority is significant, both polyester and polyether foams show good oil and solvent resistance in comparison with commercial non-oil resistant cellular materials.

Humidity aging—Although improperly formulated adipate foams tend to degrade on exposure to high humidity, improved formulations have proved quite satisfactory under normal aging conditions. Polyether foams have proved to have even greater resistance to deterioration under humid conditions.

Several test methods to determine humidity aging resistance have been developed, and the SPI (Society of the Plastics Industry, Inc.) Autoclave Test has been tentatively adopted as a standard. We believe that a long term humidity cabinet test provides a better index of the hydrolytic stability of a foam material than any short accelerated test in closed containers.

Table 5 lists results of tests conducted on the three types of foams, both in a humidity cabinet and by the autoclave method. The three types of foam follow approximately the same pattern of aging under both tests. The superior hydrolytic stability of polyether foam is emphasized by long term tests such as those carried out in the humidity cabinet. Note that the polyether foam appears to reach a plateau in loss of compression-load properties; from that point on little further change takes place. The adipate foams, however, continue to deteriorate under the severe conditions of this test.

Flame resistance—In general, the flame resistance of polyether foam is not quite as good as that of polyester foam. Reasonably good flame resistance can be produced in either foam by formulating with special additives. However, the degree of flame resistance obtained is usually not justified in the light of the deleterious effect of the additives on such properties as tear strength and resistance to humidity aging.

Adapted from a paper delivered at the Isocyanate Symposium of the Upper Midwest Section of the Society of Plastics Engineers, Inc., Oct '57.

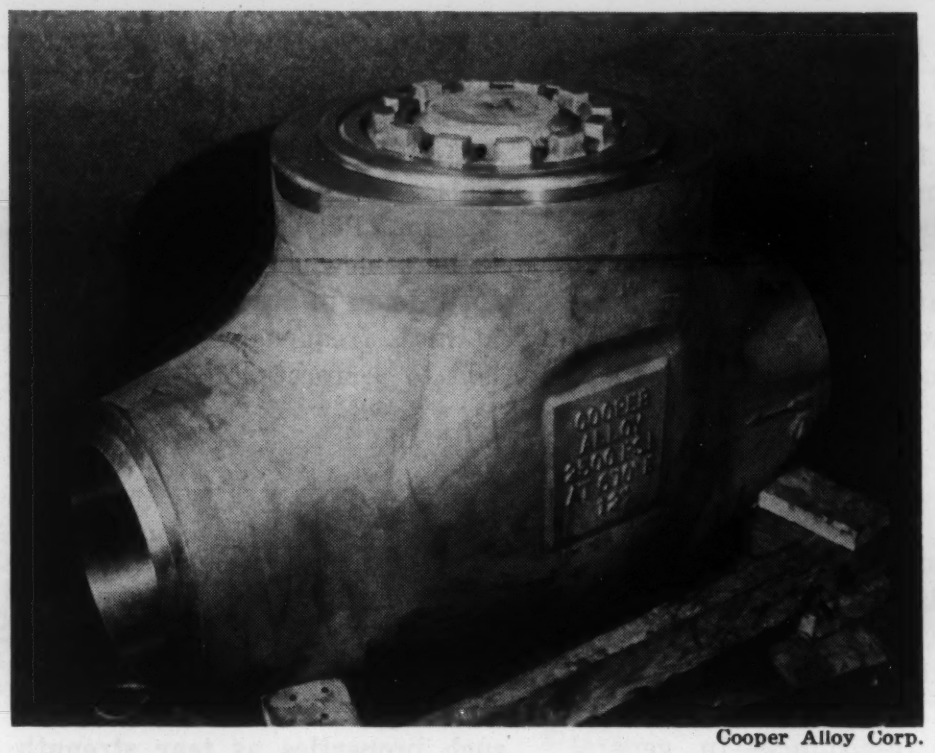
TABLE 4—CHEMICAL RESISTANCE
(% Change after 7 Day Immersion at Room Temp)

Chemical ↓	Tensile Strength		Elongation		Tear Strength	
	Adipic Polyester	Polyether	Adipic Polyester	Polyether	Adipic Polyester	Polyether
Naphtha	−29	−10	−26	− 4	− 6	+12
Benzene	−48	−23	−41	− 4	− 2	+ 9
Carbon Tetrachloride	−22	− 8	−16	0	−15	− 3
Ethyl Alcohol	−29	−16	−19	0	0	− 3
Ethyl Acetate	−37	− 4	−31	+20	− 3	+ 3
Linseed Oil	−47	−24	−49	−13	−27	+ 3
ASTM No. 1 Oil	−31	− 4	−31	+ 4	−11	+ 6
ASTM No. 3 Oil	−26	−19	−19	− 9	+ 7	0
Acetic Acid (5%)	−25	+ 2	−25	+12	− 6	+12
Sodium Hydroxide (5%)	Failed	+ 5	Failed	−29	Failed	+12
Hydrochloric Acid (5%)	Failed	+ 6	Failed	+12	Failed	+18

TABLE 5—HUMIDITY AGING RESISTANCE
(% Retention of Compression-Load after Aging)

Material ➡	Polyether	Adipic Polyester (improved)	Adipic Polyester (original)
Humidity Cabinet Test[a]			
7 Days	98	92	83
14 Days	93	86	74
21 Days	93	78	50
28 Days	90	62	Failed
56 Days	83	Failed	—
140 Days	74	—	—
Autoclave Test[b]			
3 Hr	88	78	75
6 Hr	77	70	61
9 Hr	77	62	46
12 Hr	72	58	Failed
18 Hr	70	50	—
24 Hr	72	—	—

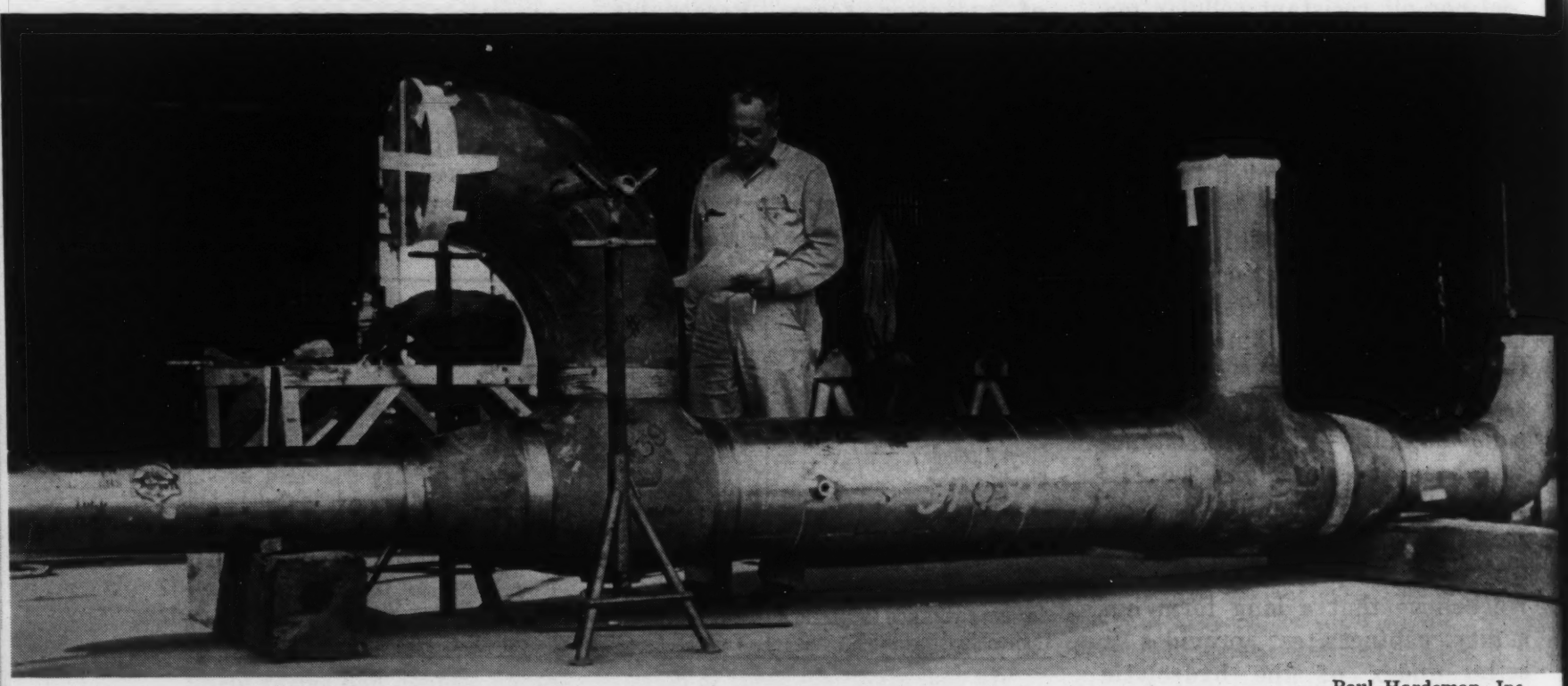
[a]Humidity cabinet at 158 F, 95-100% RH. [b]Steam autoclave at 220 F.



Cooper Alloy Corp.

Paul Hardeman, Inc.

Stainless steel check valve, tee, reducer and other fittings are welded together . . .



Paul Hardeman, Inc.

. . . to form primary loop section of nuclear reactor.

Stainless Castings with Unusual Hot Strength

Close control over solidification yields cast valves and fittings with strength of 20% higher than required by the code for unfired pressure vessels.

by Carl Tylka, *Nuclear Project Engineer, Cooper Alloy Corp.*

■ Cast stainless steel valves and fittings for high pressure, high temperature applications are now available on a production basis. As shown in Table 1, these cast parts, produced from extra low carbon 18-8 stainless steel, have

considerably higher mechanical properties than required by ASME specifications for cast or forged materials for unfired pressure vessels.

These cast fittings are used in the primary loop of an Atomic Energy Commission pressurized water reactor designed to operate at 2500 psi and 670 F. Although cast stainless valve bodies have been used in other reactors, this is the first time cast fittings have been employed in a primary loop. In addition to their nuclear energy applications, these fittings and valves, some weighing 2 tons, are used in the chemical processing and power industries.

Fittings are made in sizes ranging from 6 to 30 in. and include 45 and 90-deg elbows, tees and reducers. Valve bodies range from 4 to 30 in.

To insure conformance with specifications, all castings are tested by dye penetrant and x-ray methods; they must meet the minimum radiographic standards for steel castings given under Class 2 of ASTM specification E71. Each valve or fitting is also tested hydrostatically at room temperature to a pressure of 6000 psi.

Advantages

1. *Strength*—Because the mechanical properties greatly exceed code requirements, these castings increase the factor of safety in code work. Alternately, for non-code applications, walls can be reduced in thickness to save weight while retaining adequate strength.

2. *Economy*—Before the development of these castings, only forgings were specified for fittings to be used in nuclear energy applications. In sizes below 6 in. forgings and castings are competitive in price, but castings become less expensive with increasing size. In large fittings (about 24 in.) use of castings has resulted in savings ranging up to 40%.

Properties

The mechanical properties of production heats of cast stainless steel, Grade CF8, produced by Cooper are compared with minimum specification values in Table 2. At room temperature, yield and tensile strengths range as much as 33% higher than the specification requirements, and elongation and reduction of area range up to 50% higher than the requirement. Room temperature ductility of the castings is shown more clearly by the impact values. These range up to as much as three times the minimum required.

The code requires a minimum yield strength of 18,300 psi and a minimum tensile strength of 51,000 psi at 670 F, the operating temperature of the loop. On a sampling of 25 production heats of CF8 castings out of 150 heats made to date, yield strengths ranged from 22,000 to 27,000 psi; tensile strengths from 56,000 to 64,000 psi. Although elongation and reduction of area are not specified in the code, values obtained show high ductility at the operating temperature.

TABLE 1—YIELD STRENGTH AT 650 F

Steel	Specification	Yield Strength, 1000 psi
Cast Stainless[a]	SA351-CF8	18.3
Forged Stainless[a]	SA182-F8-304	17.9
Cast Stainless[b]	ASTM 351-CF8	22-27

[a]Minimum yield strength required by ASME Unfired Pressure Vessel Code, Section VIII, calculated by: Yield Strength = Allowable stress ÷ 62.5%.
[b]Range of test values on material produced for Atomic Energy Commission.

TABLE 2—PROPERTIES OF CF8 CASTINGS

Temp, F		Yield Strength, 1000 psi	Tensile Strength, 1000 psi	Elongation, %	Reduction of Area, %	Charpy Impact (V-notch), ft-lb
Room	Spec	30	70	35	40	50
	Castings[a]	33-40	73-82	41-59	45-62	69-150
670	Spec	18.3	51.0	—	—	—
	Castings[a]	22-27	56-64	32-46	37-52	—

[a]Range of values on 25 production heats.

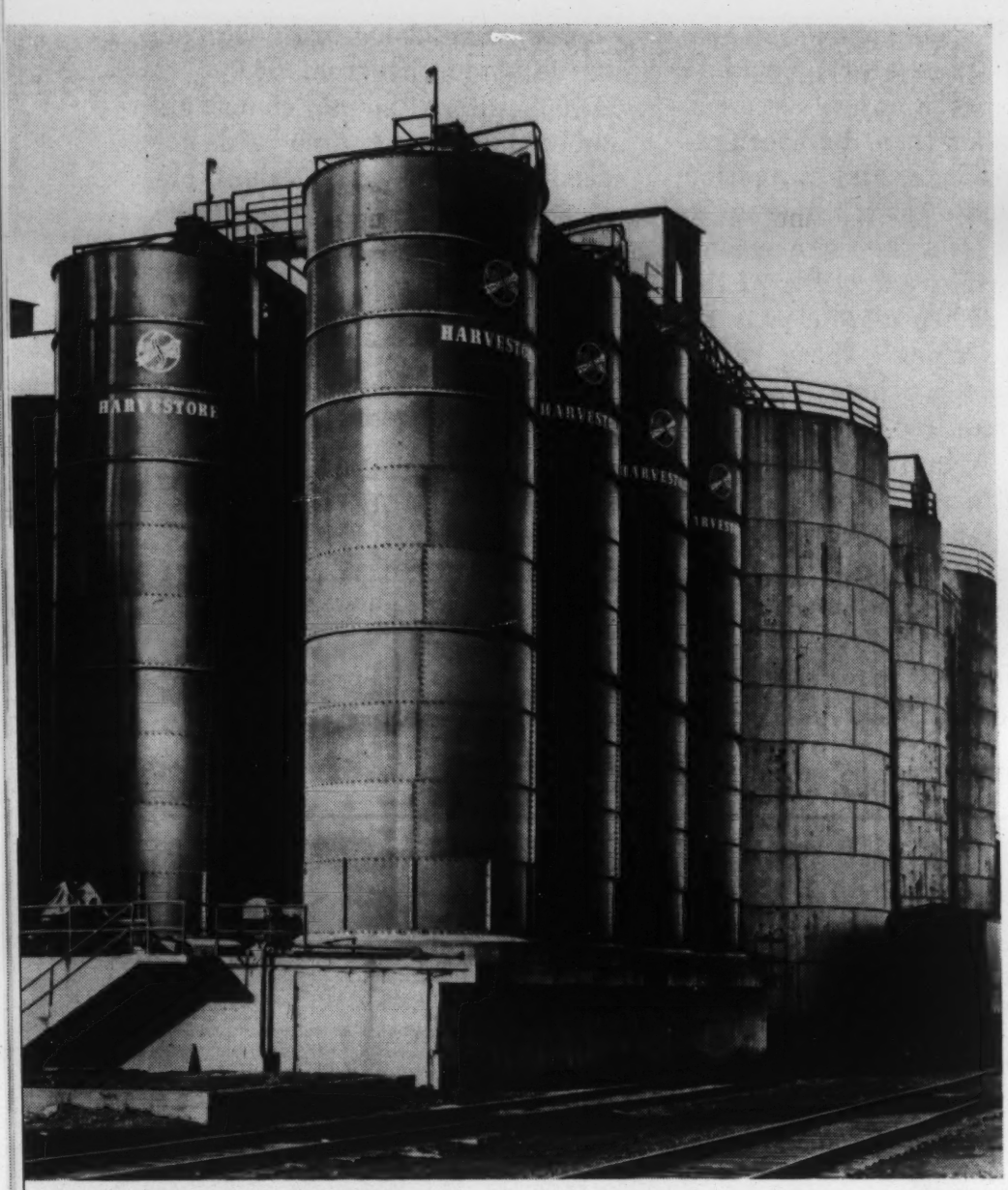
How the Castings Are Made

The most serious problem involved in obtaining high mechanical properties in a finished valve or fitting is attaining castings meeting the porosity and internal shrinkage requirements of ASTM E71, Class II or Class I X-Ray Specifications.

When stainless steel solidifies after casting it undergoes 6 to 7% volumetric shrinkage. As metal is drawn from the liquid areas to fill the resulting shrinkage voids, the final area affected is the center of the casting where a shrinkage cavity appears either as a hole or a web-like, interconnected series of fine porosity cracks, sometimes called "centerline weakness."

In many cases shrinkage voids can be prevented in the foundry by using carefully proportioned and positioned risers to feed liquid metal to the affected area. However, risering does not work if centerline shrinkage occurs in metal sections of uniform thickness. Since solidification and shrinkage proceed simultaneously from both sides of the center of a uniform section, metal freezing in the area close to the riser prevents the flow of liquid metal to the more distant side.

To eliminate centerline shrinkage, therefore, the original design incorporates a tapered, rather than a uniform, metal section. In the tapered section, solidification proceeds gradually from the thinnest section toward the thickest. The last metal to freeze lies immediately adjacent to the riser for easy feeding. This technique, called "progressive solidification," permits the routine production of large, complex castings.



storage units as installed

PRESENT—Principal uses for glass

One of the outstanding uses of corrosion resistant glasses is for coating smokestacks. About 95% of all unlined carbon steel stack failures are caused by internal and external corrosion. Moisture entrained in flue gases is cooled and condensed as the gases pass up the stack. Sulfur dioxide formed in the combustion of fuels readily dissolves in the condensate to form sulfurous solutions that attack steel. Glass lined stacks have proved extremely resistant to this form of corrosion, lasting three to five times longer than plain steel stacks in similar service. There is no need for yearly inspections and costly shutdowns are avoided. Also, since glass coatings weigh only about 5 oz per sq ft, as compared to 50 lb per sq ft for protective brick and concrete linings, they can be used with lighter weight foundations and supports.

Because of their high corrosion resistance, glass linings are ideally suited for protecting storage units and vessels. Glass linings are used to protect grain storage units that must be weather resistant on the outside and resistant to contamination on the inside.

In addition to linings for hot water heaters and brewery storage tanks, linings have been perfected for chemical autoclaves. Extreme reactions occur in these vessels (the unit shown can be used up to 330 psi), and the linings are ideally suited for resisting the constant abrasion of rough-surfaced, churning chemicals.

Glass Coatings -

A Good Way to Protect Metals

New formulations with unusually favorable combinations of properties are leading to new uses. This article describes:

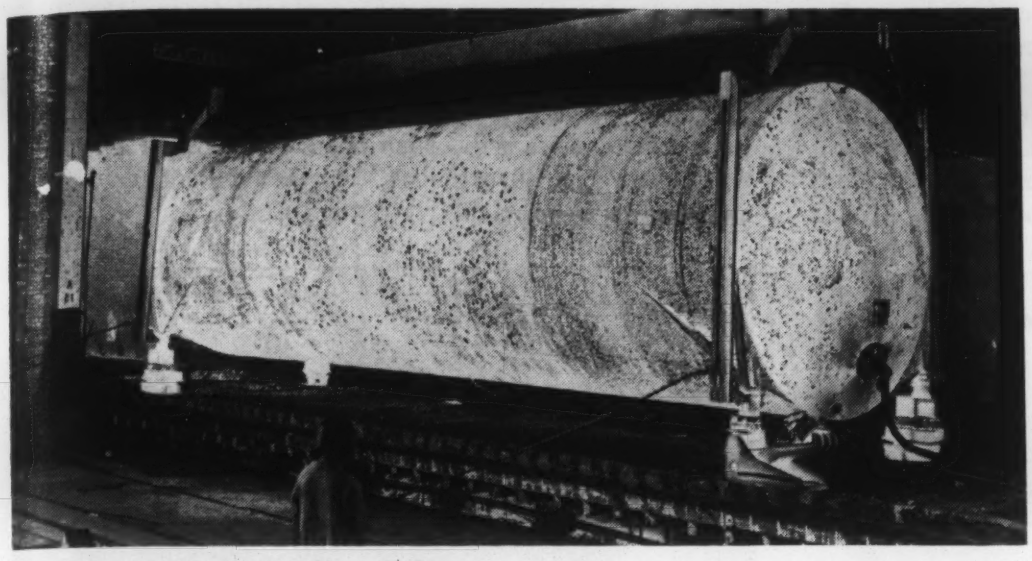
- *Chemical and mechanical properties*
- *What kind of performance you can get*
- *Design factors you must consider*

by Charles E. Bullock and Forest Nelson, *A. O. Smith Corp.*

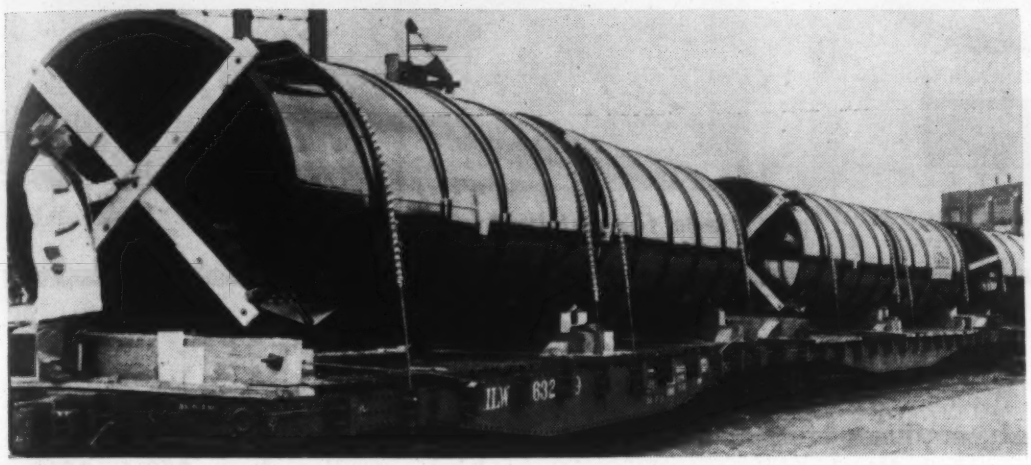
■ Glass coatings and linings are primarily noted for their high resistance to corrosion and for their long trouble-free service in hot water heaters and liquid storage tanks. In the past, the high corrosion protection offered by the coatings has tended to overshadow their other significant engineering properties; namely, their high hardness, abrasion resistance and dielectric strength, low coefficient of friction, and good to excellent heat and oxidation resistance. Recent development of new glass formulations designed to take advantage of this unique combination of properties has led to a host of new applications.

What is a glass coating?

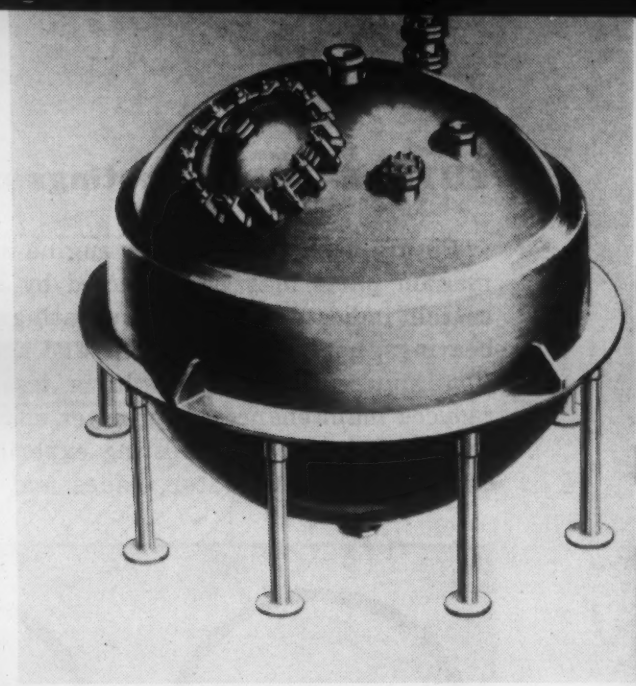
Over 50 different inorganic raw



Brewery tank just after firing



Smokestack sections enroute to site



Chemical reactor of new design

materials are presently used in compounding glass coatings, and well over 3000 formulations are available. Any one formulation usually contains only 10 or 12 basic materials, selection of which depends upon the end use of the coating. Typical coatings for steel consist basically of silica and alumina, and oxides of boron sodium and potassium.

Silica is the basic ingredient of all glass linings. Alumina is used to improve corrosion resistance, and cobalt to provide adhesion. In varying degrees, sodium, potassium, boron and fluorine all serve to lower the melting temperature of the glass. In addition they also possess individual properties that are taken into consideration for each formulation.

Glass coatings and porcelain enamels are quite similar, differing primarily in end use. Porcelain enamels are usually, but not always, used to improve the appearance of, and give protection to, consumer products. Usually applied over light gage metal, they are long wearing, resistant to citric acids and other mild acids, fairly resistant to abrasion, and usable at low temperatures. Glass linings, on the other hand, are used primarily for heavier duty industrial applications and are usually applied to heavy gage metal.

Properties

Corrosion resistance — Glass coatings can be formulated to resist a wide variety of corrosive media. For example, they can be made to resist all organic acids and inorganic acids except hydrofluoric (which dissolves silica, a major component of glass). In many cases the corrosion resistance of glasses actually improves with increasing acid concentration up to operating temperatures of 300 F. Under certain conditions this temperature limit can be exceeded. (See graphs on p 109 for practical temperature - concentration limits in four common acids.)

Despite the fact that silica is naturally soluble in alkalis, formulations can be produced that withstand pH up to 12 at 210 F. Glass linings are frequently used in laundry equipment and dishwashers where high resistance to alkali detergents is needed.

The resistance of glass linings

PROPERTIES OF GLASS LININGS

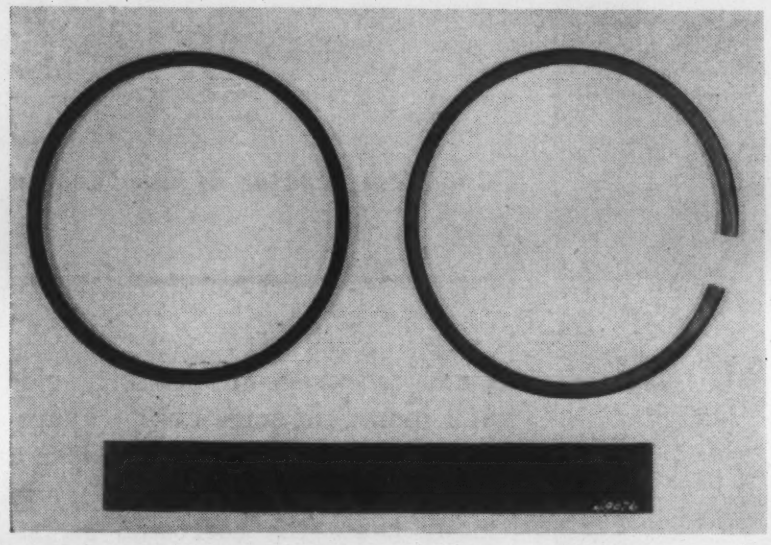
PHYSICAL PROPERTIES	
Specific Gravity	2.56
Modulus of Elasticity, psi	$6\text{-}9 \times 10^6$
Moh Hardness	6
Adhesion Strength, psi	5-10,000
Dielectric Strength, v/mil	600-1000
CHEMICAL RESISTANCE	
Organic Acids	All
Inorganic Acids	All except hydrofluoric
Alkalis	Up to 12 pH at 210 F
THERMAL PROPERTIES	
Coef of Ther Exp (avg), per °F	$50\text{-}208 \times 10^{-7}$
Max Operating Temperature, F	500[a]
Thermal Shock Resistance, △°F	305

[a]For chemically resistant glasses only. Special high temperature glasses will withstand 1500 F.

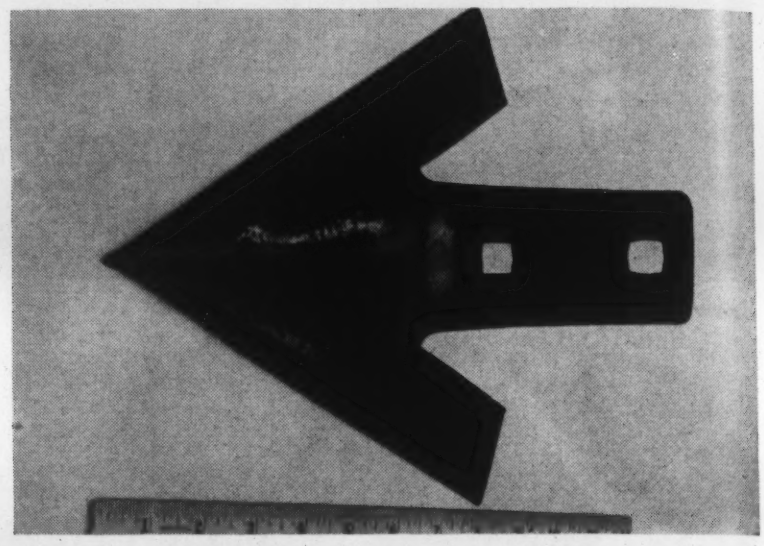
FUTURE—Glass coatings may be widely used for automotive, agricultural equipment

Future designs of moving engine and automatic transmission parts may be protected by special glasses. Research indicates that glass coatings on parts such as bearings, gears, cams, pistons and rings will reduce friction appreciably and result in less wear, longer life, reduced maintenance and greater efficiency.

One of the most interesting experimental uses of glass coatings is on cultivator blades and plowshares. Under ordinary field conditions unprotected blades are subject to extreme wear and must be replaced frequently. Glass coated blades, however, reduce friction and increase resistance to abrasion and corrosion. They provide much longer life, and are capable of markedly reducing maintenance. The glass will crush if it comes in direct contact with sub rock; nevertheless, the damage incurred is not expected to be particularly detrimental.



Automotive piston rings



Blade for cultivator

to hot water is well known. Hot water will corrode most engineering materials, and even some acid resistant glass linings; however, special glass formulations are available that resist all types of water in all geographic locations.

Heat and oxidation resistance—In general, the peak operating temperature of most glass coatings is about 500 F. In recent years, however, special formulations have been developed for protecting metals (such as jet exhaust ports) at extreme temperatures. Coatings have been developed to protect carbon steels from oxidizing at continuous operating temperatures of 1250 F, and to protect stainless steels up to 1500 F. Means of further extending these limits are being sought.

Many formulations are also distinguished by their high resistance to thermal shock. In some cases they will withstand a temperature differential up to 305 °F. Formulations can be produced with a coefficient of expansion which closely matches that of any base metal. For example, formulations have been developed for 410 stainless steel and Invar materials with low temperature inversions.

Other properties—In addition to their inert composition, glass coatings possess a smooth surface which is free from pores and impervious to absorption. They also have extremely high abrasion resistance and high hardness (about 6 Moh). Dielectric strength is also high, ranging from 600 to 1000 v per mil.

Adhesion of glass linings to metals is usually thought to occur by a mechanical bond. Actually, the bond is largely chemical and is of such strength that it cannot be measured by the ordinary

How Glasses Are Made

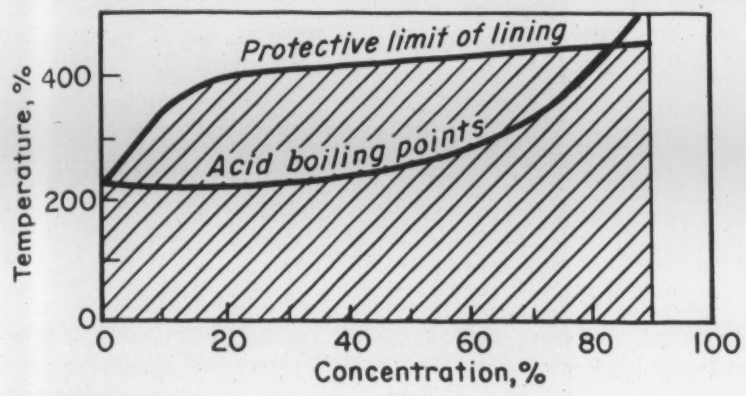
In producing glass for coatings the elements (see text) are blended together and charged into a box smelter. The materials are heated to a molten state—about 2300 F—and quenched in cold water which shatters the glass into small pieces called "frit."

The frit and a special ball clay are then milled into a fine powder and added to water to make a solution called a "slip." This slip is applied to cleaned surfaces by spraying, dipping or flow coating.

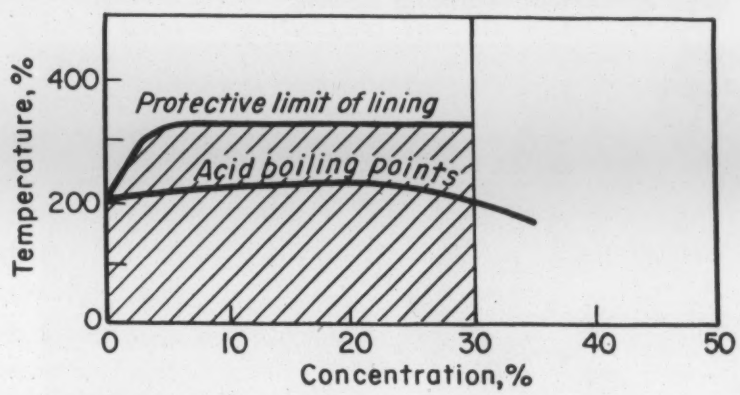
After application, the coating is dried at 300 F and then fired. Firing temperature depends on the glass formulation, but is usually 1600 F. Firing time depends on thickness of the metal, and shape and structure of the part.

One glass coat is sufficient for many types of service. However, where service is liable to be severe, three to five coats may be required. Chemical ware is tested by visual inspection, and also by electrical tests using a 30,000-v spark tester which detects pinholes and punctures thin spots.

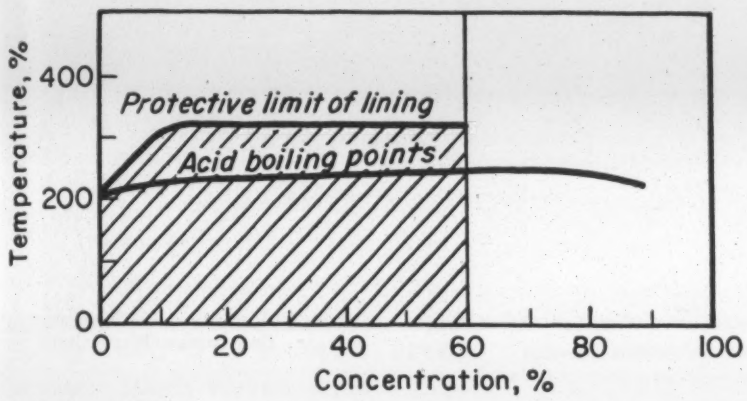
Resistance of glass linings to . . .



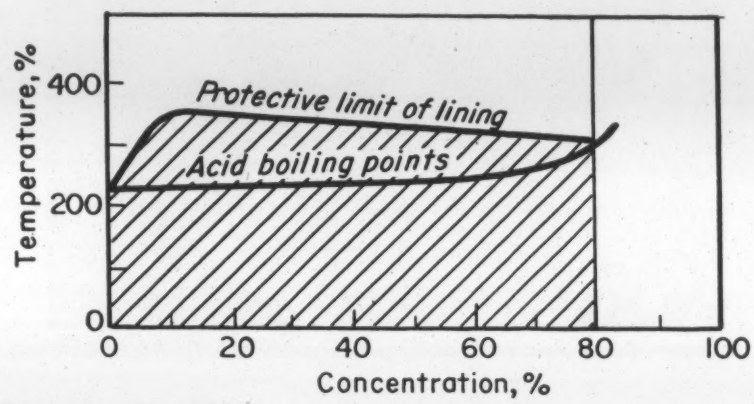
Sulfuric acid



Hydrochloric acid



Nitric acid



Phosphoric acid

means used for organic coatings. Tests have shown values of adhesion strength up to 10,000 psi.

Design factors

Base metal selection—Glass linings can be fused to a variety of metals, such as copper, aluminum, silver, gold and stainless steel. Most industrial applications, however, utilize low carbon steels as a base metal.

Selection of the proper type of carbon steel is quite important in order to obtain a good coating. For example, a rimmed steel (ASTM A285), grade A or B flange quality, with a carbon content of less than 0.20% is usually required for glass lined brewery storage tanks, chemical processing reactors and water heater tanks. With this steel as a base, such defects as fishscaling, blistering, crazing and poor adhesion are avoided.

Thickness—In designing a tank or vessel, the thickness of the base metal is usually a function of operating pressure and temperature. However, where a glass lining is used, the strength of the vessel at 1600 F (the temperature required to fuse glass to steel) may well be the controlling factor.

For example, ordinarily an unlined brewery tank with a ¼-in. wall and ⅜-in. heads would be sufficient to withstand pressure of 15 psi. However, if a glass lining were to be applied to this same tank, the structure would sag and distort when fired at 1600 F in the glass coating operation.

Consequently, greater section thicknesses are sometimes required, not because of actual operating conditions, but because of the high glass firing temperature.

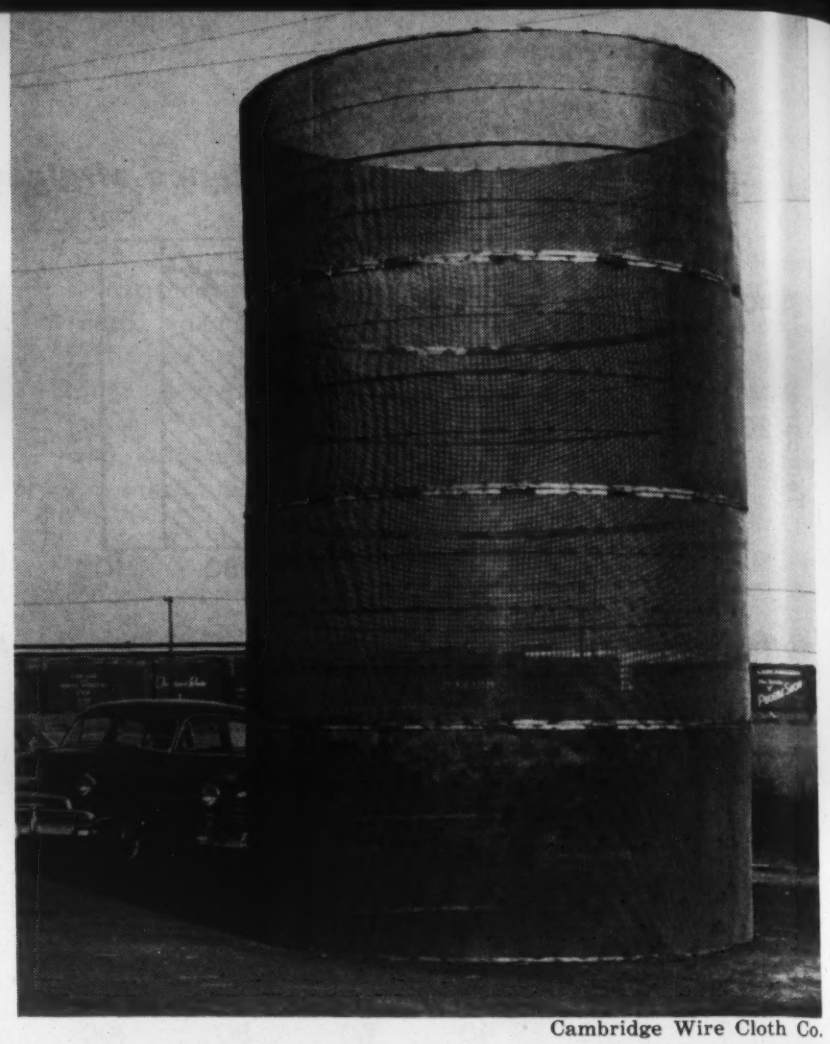
Thermal stress—This is another problem to be considered in designing a product for use with a glass coating. For economy reasons, parts are usually heated to the glass firing temperature as quickly as possible. Unless the part is properly fabricated this rapid temperature rise will induce stresses and distortions. These can usually be avoided by designing the part so that all sections are heated up at the same rate. Welding of heavy sections to light sections should be avoided whereever possible.

Weld deposits—Glass coatings can be successfully applied to weld deposits provided that proper control is exerted. Composition of welds should be similar to that of the base metal to insure a common reaction to heating and cooling during the glass firing operation. Flash welds and oxyacetylene welds can be coated satisfactorily provided they have a smooth finish and are free of pinholes, dirt and grease.

Coated electrodes used in manual welding will produce satisfactory results if the above conditions are maintained and if the deposits are free of hydrogen and cellulosic and carbonaceous materials. Hydrogen in weld deposits is emitted as the glass coating cools after firing and can cause defects in the coating. In order to eliminate hydrogen it is usually necessary to bake the electrodes to at least 600 F to drive off all moisture, and to seal the electrodes against moisture until they are ready for use.

Small and large—*Uses for wire cloth range from small strainers used in aircraft and appliances to huge cylindrical retaining screen.*

Newark Wire Cloth Co.



Cambridge Wire Cloth Co.

How to Select Woven Wire Cloth

Weave, wire size, capacity, material—these are some of the important factors you must consider in preparing a specification.

by John L. Everhart, *Technical Editor, Materials in Design Engineering*

■ Woven wire cloth is used in a wide range of industrial applications for grading, filtering, straining, washing, guarding, reinforcing and decorating. The requirements of specific applications are so varied that each must be considered from such standpoints as operating temperature, corrosion resistance, vibration and imposed load. To meet these different requirements, a variety of meshes has been developed, each produced in a range of sizes and materials. Becoming familiar with the characteristics of these meshes and materials will enable you to make an initial choice and to consult intelligently with a producer of wire cloth in the final selection.

Selection of the cloth

1. Determine type of weave. Most common weave is the plain, or square, weave but a number of other weaves have been developed, each having advantages for a certain type of service. Some of the more common weaves are illustrated and discussed briefly on page 112.

2. Determine "space." Since "space" is the actual size of opening, selection depends mainly on the size of particle or object to be separated or excluded by the cloth. The distinction between space and "mesh" is important (see definitions, p 111). For example, two cloths of different mesh and different wire size can have the same space or size of opening, i.e., a square mesh screen with ¼-in. opening could be 3 x 3 mesh with 0.080-in. wire or 2½ x 2½ mesh with 0.148-in. wire.

3. Determine wire size. The capacity of wire cloth depends on both space and wire size. The two cloths mentioned in *2* above, for example, have equal openings, but the cloth with the smaller wires has a total open area of 57.6%, compared with 39.7% for the cloth with the heavier wires, and thus a greater capacity. On the other hand, the cloth with the greater capacity can be expected to have a shorter life than the heavier cloth.

Open area can be determined by the following formula:

Area = (1—ND) (1—nd)

where N = number of wires in warp per in.
n = number of wires in shoot per in.
D = dia of wires in warp
d = dia of wires in shoot

4. **Determine mesh.** Mesh in square or rectangular mesh cloth is determined by adding space and wire diameter together in each direction and dividing each total into the unit *1*. For example, if the space in the warp direction is 0.048 in. and the diameter of the shoot wire is 0.035 in., the sum in the warp direction is 0.083 in. The reciprocal of this sum is 12 which is the warp mesh.

As indicated previously, cloths of the same mesh can have different openings and wire sizes. For example, a 2 x 2 mesh cloth with 0.120-in. wire has a 3/8-in. opening and 57.8% open area; the same mesh woven with 0.177-in. wire has only a 5/16-in. opening and 41.7% open area.

In order to avoid confusion, include wire size in specifications, giving it in thousandths of an inch. Always gives the size of the warp wire first, the shoot wire second. For example, 7 x 4 mesh, 0.035″/0.063″ means: 7 mesh and 0.035-in. wire in the warp; 4 mesh and 0.063-in. wire in the shoot.

Selecting the material

Wire cloth can be produced from any metal that can be drawn into suitable wire that is sufficiently ductile to permit weaving. Among the more common materials are carbon steel, stainless steel of various grades, copper, brass, bronze, nickel, monel, Inconel and aluminum.

Standard industrial wire cloth is generally made in a variety of mesh sizes, depending on the material. Thus, square mesh cloth in plain weave is generally produced in carbon steel to 60 x 60 mesh; in aluminum to 70 x 70 mesh; in brass to 120 x 120 mesh; in copper to 100 x 100 mesh; in monel to 200 x 200 mesh and in phosphor bronze, monel and stainless steel to 325 x 325 mesh.

Selecting the metal to be used in wire cloth should be done only after a trial under the specific conditions of use. However, since certain materials have been used successfully in varied applications, it is possible to make some broad generalizations as a basis for preliminary selection.

Plain steel wire cloth is the most widely used material for general service and greatest economy. However, it is subject to rusting. If the use is decorative, a coating may be required to preserve an attractive appearance. Coatings may also be required in screening operations, since formation of rust will blind the screen and reduce its efficiency.

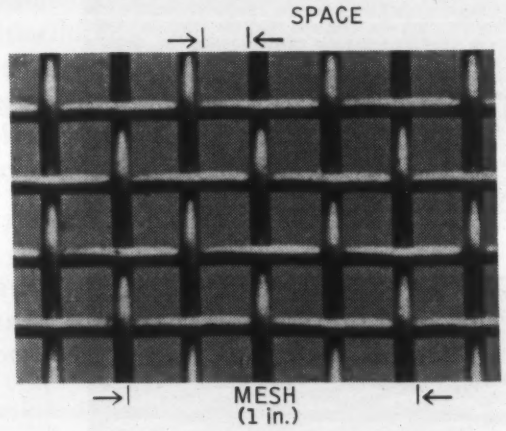
The most common method of overcoming this problem is to use cloth woven from tinned or galvanized wire; tinned wire is preferred for handling food products, galvanized for all other applications. For service under severe conditions, cloth that has been galvanized after weaving is preferred because the coating is thicker than that applied to precoated wire. This coating has the additional advantage of forming joints at the wire intersections and increasing the rigidity of the mesh. However, it should not be specified for cloth finer than about 8 mesh. A more expensive, and therefore less frequently used, method of protective coating is electroplating of the woven fabric with cadmium, chromium or tin.

Protective coatings can also be applied by phosphate coating,

Some Important Definitions

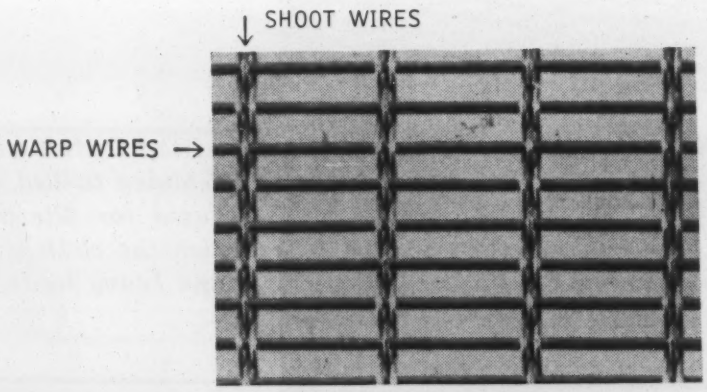
Space *The width of clear openings between parallel wires. It is customary to designate the size of openings in inches.*

Mesh *The number of openings per linear inch measured from center to center of parallel wires. For example, a No. 4 mesh has four openings in a linear inch.*



Warp wires *The wires running the long way of the cloth as woven.*

Shoot wires *The wires running the short way of the cloth as woven.*



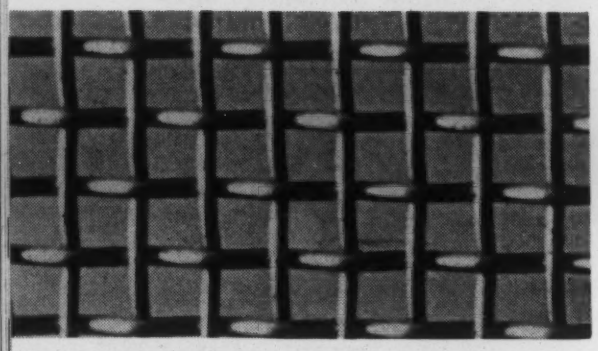
Coarse mesh[a] *Cloth with a mesh count of less than 30 by 30.*

Medium mesh[a] *Cloth with a mesh count of 30 by 30 to 90 by 90 incl.*

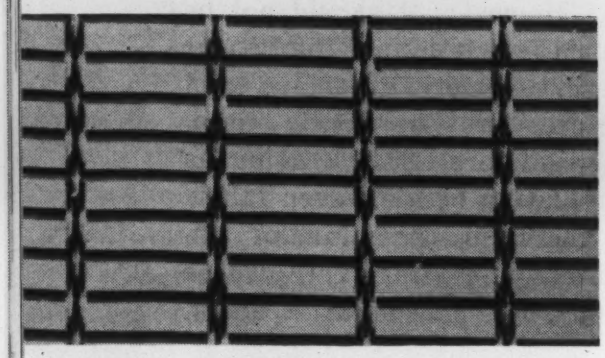
Fine mesh[a] *Cloth with a mesh count finer than 90 by 90.*

[a] Federal Specification RR-C-440.

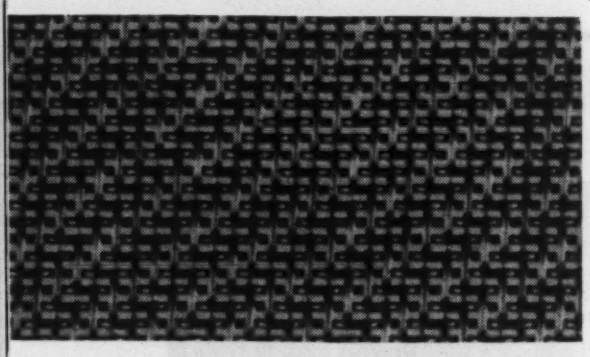
Types of Weaves



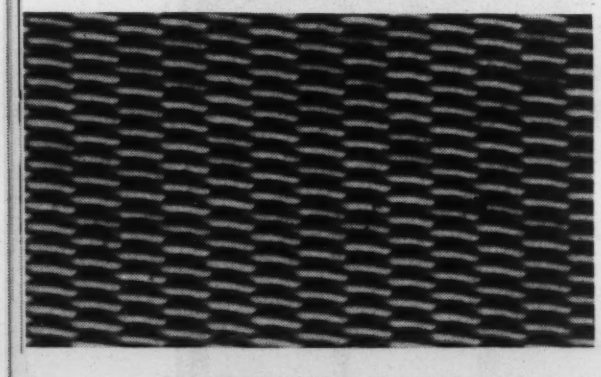
***Square weave** is the simplest and most commonly used wire cloth weave. It permits positive control of the size of materials to be screened, strained or filtered.*



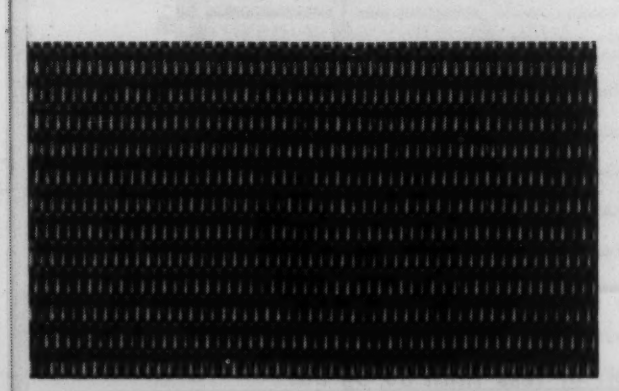
***Rectangular weave,** differing from square weave only in having the mesh count greater in one direction than the other, is often used for economy because it is easier to loom than square weave. It is particularly suited to the separation of materials that are not round or square; one use is the grading of seed. (Photo shows triple warp weave.)*



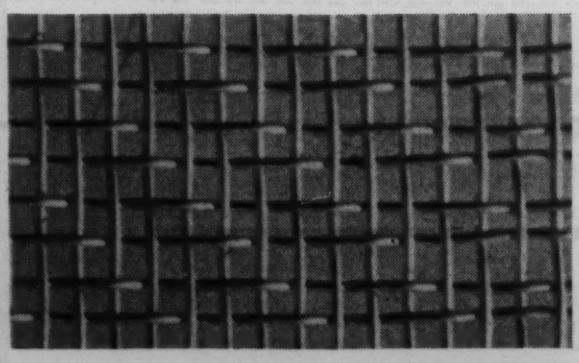
***Twilled weave** is produced by passing each shoot wire alternately over and under two warp wires instead of one. Twilled weave can be produced with square or rectangular openings, but is stronger than the plain weaves mentioned above. It is used particularly where the cloth must withstand relatively heavy loads.*



***Dutch weave** is produced by using heavier wire in the warp than in the shoot and forcing each shoot wire tightly against the next one. It is used primarily as a filter cloth.*



***Twilled Dutch weave,** produced by combining twilled and Dutch weaves, is used for filtering applications in which the cloth is required to withstand heavy loads.*



***Herringbone twill weave** is produced by reversing the ridges of a twilled weave at regular intervals. It is used primarily for its decorative effect where the cloth will be visible in the finished product.*

Photos from Reynolds Wire Div., National Standard Co.

Michigan Wire Cloth Co.

***Redesign** with Dutch weave (left) produced a filter that can be made more easily and at less cost than conventional filter (right).*

varnishing or painting. Plastics coatings of various types are used for decoration, for electrical insulation and for certain food handling uses.

Corrosion—The problem of selection for service in corrosive environments differs only in degree from that encountered with any corrosion problem. Generally, only the most resistant material available is satisfactory as woven wire because of the small diameter and large surface area involved. Among the materials most used are various stainless steels, monel, brass, phosphor bronze and silicon bronze. Some of these materials are available only in limited mesh sizes.

Abrasion—To handle abrasive materials, it is generally advisable to select special abrasion resistant steels. However, these steels are difficult to work and usually can be obtained only in relatively heavy mesh because of difficulty in drawing wire finer than about 18 gage. For finer abrasive materials, stainless steels, monel and possibly phosphor bronze are suggested.

Heat—For handling hot materials, the selection of a suitable alloy wire depends on the temperature. Up to 1400 F, stainless type 347 is useful; for temperatures to 1600 F, stainless types 309 and 310 can be used; and for temperatures to 2000 F stainless

Some applications of wire cloth

Filtering and straining

Although related, the two terms are generally distinguished by their intended application. Filtering is the separation from a liquid or a gas of a material known to be present. Straining is the removal of material that should not be present; thus the operation is a protective device to assure proper operation of equipment.

Square mesh cloth coarser than about 80 x 80 mesh is used in process filtration, but finer sizes are generally not used because of low strength and service life. The most common type of filter cloth is Dutch weave. In forming this cloth each shoot wire is forced against the adjacent wire, and the only open area results from passage of the shoot wires over and under the warp wires. Since the openings are wedge shaped through the cloth, calculation of open area is impractical; thus, size retention of this type of cloth must be determined by tests.

Although filter cloth was originally used almost entirely in the process industries, it is now being used to replace square mesh in fabricated strainers in industrial equipment and consumer goods.

Strainers have a wide variety of industrial uses. In the automotive and aviation industries, particularly, they are used for carburetor air screens, oil and fuel strainers, and strainers for hydraulic fluids. They are also used to remove dust from air and to prevent clogging of liquid pumps.

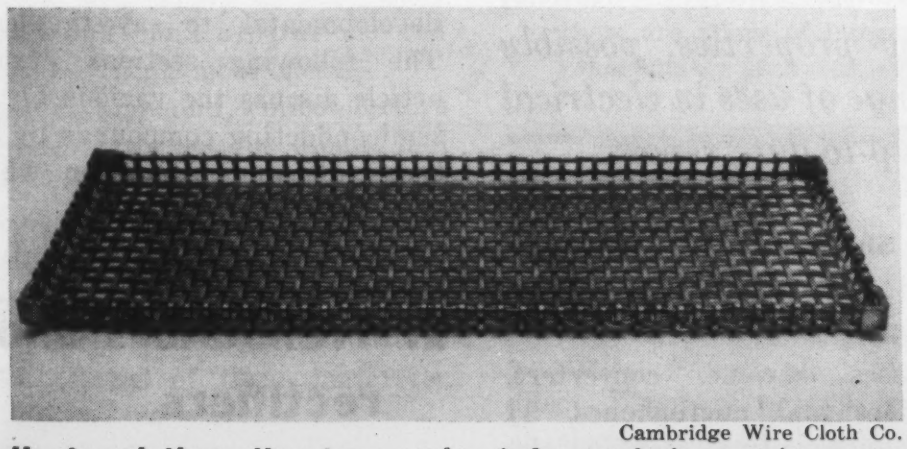
Other applications

▸ Wire cloth screens are used in grading a wide variety of materials ranging from coarse rock to –325 mesh powders. Among the products separated in this manner are coal, limestone, talc and metal powders.

▸ Wire baskets of various types are used for washing food products and for handling small parts in such production operations as degreasing, pickling and heat treating.

▸ Based on consumption, the most important woven wire product is insect screening. This product is covered by Commercial Standard 138-55, and requirements are strictly defined. Only three metals—galvanized steel, commercial bronze and aluminum alloy equivalent to 5056-cladded—and only two weaves, 18 x 18 and 18 x 14 mesh, are included in the specifications. These screen sizes were selected as the result of extensive tests with live mosquitoes. The tests showed that 18 x 14 mesh is the largest size that can be used to screen out the insects; 18 x 18 mesh is used only for seashore installations where the insects are small. Wire diameter is just as important as mesh. The standard requires use of wire of not less than 0.011 in. dia for steel and bronze, and 0.013 in. for aluminum; wire of smaller diameter would increase the size of the opening and reduce screening efficiency.

▸ Woven wire is used to protect operators from moving machinery and to protect property from pilfering. Screening is used as conveyor belting, as in heat treating furnaces; coarse screens are frequently used as backing for finer screens to add strength and rigidity to the installation. Brake linings are reinforced with woven wire, and the material is also used for reinforcing various plastics and rubber articles. Various special weaves are produced for decorative applications in architectural and consumer products.



Cambridge Wire Cloth Co.

Heat resisting alloy tray *made of flat mesh for use in copper brazing at 2150 F.*

Michigan Wire Cloth Co.

Strainers *protect automotive automatic transmissions from damage.*

type 310, Inconel and Nichrome are suitable. However, Inconel and Nichrome cannot always be obtained in the wire sizes desired.

Acknowledgment

The following organizations assisted in the preparation of this article:

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Cambridge Wire Cloth Co.
Industrial Wire Cloth Inst.
Michigan Wire Cloth Co.
Newark Wire Cloth Co.
Reynolds Wire Div., National-Standard Co.

REPRESENTATIVE SEMICONDUCTORS—PROPERTIES AND APPLICATIONS

Material	Band Separation (at 300 K), ev	Mobility (at 300 K), cm/v-sec		Melting Point, F	Application
		Electrons	Holes		
Germanium (Ge)	0.72	3600	1900	1708	Rectifiers, transistors
Gallium Antimonide (GaSb)	0.6[b]	3000[b]	1000[b]	1295	
Silicon (Si)	1.12	≤ 2000	≤ 500	2588	High temperature rectifiers and transistors; solar batteries; infrared optics; photocells
Indium Phosphide (InP)	1.27	4000[b]	650	1922	
Gallium Arsenide (GaAs)	1.34	5000[b]	300	2262	
Cadmium Telluride (CdTe)	1.45	≤ 1000	100[b]	1913	
Aluminum Antimonide (AlSb)	1.6	400[b]	400	1922	
Cadmium Sulfide (CdS)[a]	2.4	250[b]	—	—	
Gold-Doped Ge[a]	0.72	3600	1900	1716	Infrared detectors; filters
Mercury Telluride (HgTe)[a]	≤ 0.06	≤ 17,000	—	1238	
Indium Antimonide (InSb)	0.16	75,000	800	972	Magnetoresistance devices; Hall effect devices; thermistors
Indium Arsenide (InAs)	0.33	40,000	600[b]	1727	
Lead Telluride (PbTe)	0.3	2000	1100	1688	Infrared detectors
Lead Selenide (PbSe)	0.26	1200	600	1976	
Lead Sulfide (PbS)	0.4	800	400	2048	
Bismuth Telluride (Bi_2Te_3)[a]	0.16	570[b]	400[b]	1076	Thermoelectric devices
Cadmium Antimonide (CdSb)[a]	0.5	—	400[b]	852	

[a]One compound of a family of two or more related compounds. [b]Minimum value.

Where to Use The New Semiconductor Materials

Complementing the established semiconductor metals, intermetallic compounds offer new properties, possibly lower cost, and certainly a wider range of uses in electrical and electronic devices. Here is an up-to-date report.

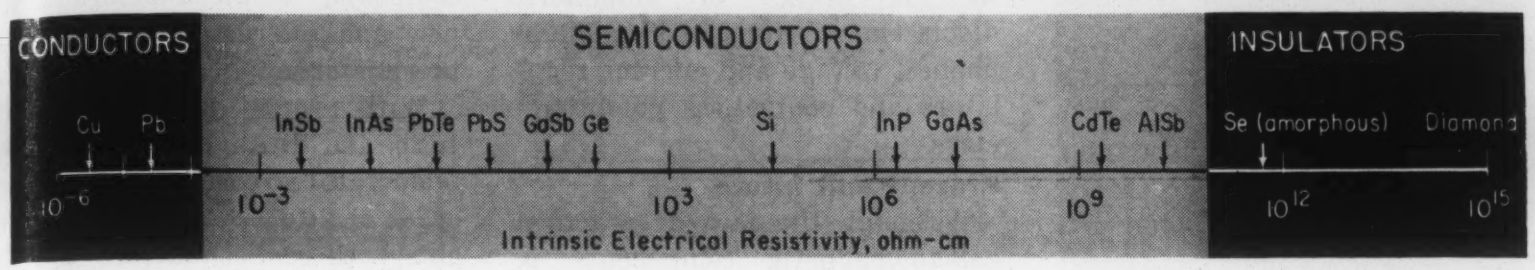
by Robert K. Willardson and Theodore S. Shilliday,
Battelle Memorial Institute

■ The accompanying table lists representative semiconductor materials, their properties, and present or anticipated applications for them. Some of the more promising applications for the new intermetallic compounds include: 1) rectifiers and transistors that will operate at high temperatures, 2) galvanomagnetic devices, such as computer elements, electronic compasses, d.c.-a.c. converters, amplifiers and microphones, 3) thermally sensitive, resistive elements known as thermistors, 4) optical devices such as infrared detection systems and solar batteries which make use of the photoeffects peculiar to semiconductors, and 5) thermoelectric devices for power generation or refrigeration.

Most of these applications are developmental, to say the least. The following sections of the article discuss the various binary semiconducting compounds by the types of application for which they seem best suited.

1. Transistors and rectifiers

Energy band separation in the semiconductor material imposes an upper limit on the ambient temperature or power density for which a transistor or rectifier can be rated. Generally, a larger band separation raises the limit of temperature and power density.



Also, charge carrier mobility in the semiconductor directly influences frequency response and other characteristics of the device. The higher mobilities are more desirable.

Germanium and silicon transistors are operable at temperatures up to about 185 and 390 F respectively. As can be seen in the table of properties, indium phosphide (InP) and gallium arsenide (GaAs) have mobilities higher than germanium, and their band separations should permit transistor operation at temperatures of about 570 to 850 F. For transistors operable at temperatures of 850 to 1000 F, aluminum antimonide (AlSb) appears promising. For even higher temperatures silicon carbide (SiC) is potentially useful.

Where low temperature operation is required, or where a low ambient temperature can be maintained to achieve high frequency performance, indium antimonide (InSb) and indium arsenide (InAs) may prove useful. They have small band separations and extremely high mobilities.

Thus, compound semiconductors provide materials for diodes and transistors operable over the temperature range of –290 to 1000 F. Developmental transistors exhibiting usable amplifications have actually been made in the laboratory from several of these materials.

Semiconductor Materials: More to Come

Semiconductors are quite literally half conductor, half insulator. Their conductivity lies between that of conductors and that of insulators. The accompanying charts show 1) how semiconductors compare in resistivity with conductors and insulators, and 2) the electrical effects they make possible and some of the resulting uses. (For a discussion of how semiconductors work, see MATERIALS & METHODS, July '54, p 92.)

The new materials

By far the best known and most widely used semiconductor materials are elements silicon and germanium. In the next few years such intermetallic compounds as indium phosphide, gallium arsenide, aluminum antimonide, indium antimonide and indium arsenide, to mention just a few, will become increasingly important. There are also many more binary compounds which are as yet uninvestigated; there are ternary compounds such as the chalcopyrites, of which silver indium telluride is one; there are alloys of intermetallic compounds, such as gallium antimonide with aluminum antimonide, or indium phosphide with indium arsenide; and there are the organic semiconductors, such as the phthalocyanines.

The binary intermetallic compounds hold the greatest current interest, and are the ones we know the most about. They offer great promise in extending the practical use of semiconducting materials in designing new electrical or electronic products.

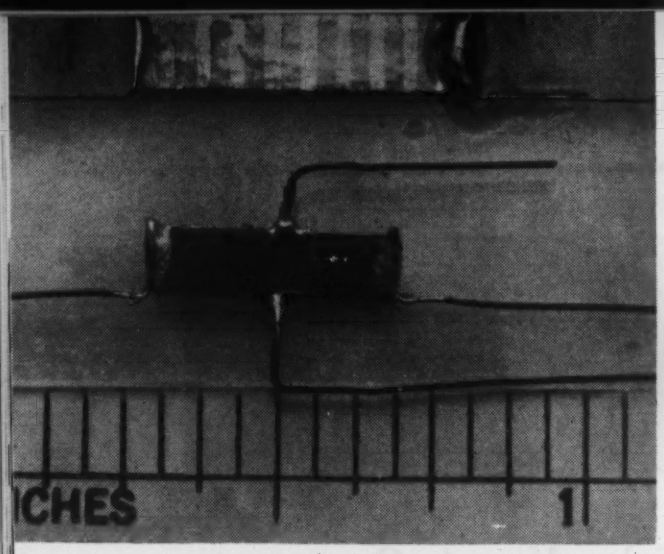
Availability

At present only five of the semiconducting compounds discussed here are known to be commercially available in the United States: bismuth telluride and gallium arsenide (United Minerals Co.), indium antimonide and indium arsenide (Ohio Semiconductors, Inc.), and lead telluride (Minnesota Mining and Mfg. Co., Ohio Semiconductors, Inc., and A. D. Mackay, Inc.). The other compounds discussed, and many additional ones, are to be found only in research and development laboratories, or on special order from manufacturers who utilize them in their products.

2. Galvanomagnetic devices

InSb and InAs compounds, with their high charge carrier mobility, appear promising for use in galvanomagnetic components. Such components make use of the characteristic known as the Hall effect: When a conductor carrying an electric current is placed in a magnetic field which is at right angles to the direction of current flow, the electrons that compose the current are forced toward one side of the conductor. This piling up of electrons creates a difference in electron density at the sides of the conductor. The potential difference, called the *Hall voltage*, created by the density differential builds up to such a value that the resulting transverse electric field exerts a force that is equal and opposite to that of the magnetic field.

Another phenomenon based on the Hall effect can be put to use. The Hall voltage can be shorted out, causing a transverse current to flow. This transverse current, which flows in a direction normal



Galvanomagnetic devices *have at their heart elements such as these made of indium antimonide. The element at bottom produces a Hall effect, the element at top is a magnetoresistor. The latter is 0.003 in. thick and without a magnetic field has a resistance of 2 ohms. When placed in a 10,000 gauss magnetic field, the gold strips short out the Hall voltage, and resistance of the element increases to 20 ohms.*

to the magnetic field, creates another Hall potential which opposes the flow of the primary current in the conductor. The result is a large increase in the effective resistance of the conductor (known as a *magnetoresistance effect*). Thus, the primary current can be controlled by varying the magnetic field.

Some practical uses

Each of these phenomena can be utilized in the design of several unique semiconductor devices. InSb and InAs are particularly promising for such uses because, in most instances, the performance of such devices is improved by using semiconductors with high charge carrier mobilities.

Since the Hall voltage is proportional to the product of the electric current and the magnetic field, it can be used in the design of analog and digital computer elements, detector elements in magnetometers, clip-on d.c.-a.c. ammeters, electronic compasses, d.c.-a.c. converters, and low level amplifiers.

The magnetoresistance effect is proportional to the square of the product of mobility and magnetic field strength. Resistance changes of up to 90:1 at fields of 30,000 gauss have been obtained in InSb elements. This effect can be used in the design of amplifiers, displacement transducers, microphones, voltage and current regulators and contactless potentiometers.

Present and future

Although the idea of practical galvanomagnetic components is relatively new, laboratory models of several of these devices have already been successfully constructed. They include displacement gages capable of detecting movements as small as 10^{-5} cm, amplifiers exhibiting gains of the order of 10 to 15 db, magnetic compasses sensitive to less than 1 deg change in azimuth, microphones, various forms of choppers, and computer elements.

Experimental results achieved to date are only preliminary ones and can be markedly improved. For example, calculations indicate that in InSb amplifiers of optimum design, gains of 30 to 40 db can be obtained at room temperature. Cooling the device to the temperature of liquid nitrogen should increase the gain to over 60 db.

3. Heat sensitive resistors

The peculiar effect of temperature on the resistivity of semiconductor materials makes them useful in heat sensitive resistance elements known as thermistors. Some of the most interesting of the compound semiconductors for this type of use are InSb and InAs, lead selenide (PbSe), silver sulfide (Ag_2S), and solid solutions of barium strontium titanate.

Negative coefficients

The large negative temperature coefficient of resistance of some types of semiconductors has been used for a number of years in thermistors. Operation of these thermistors is based on the fact that the number of electrons (or positive carriers) free to carry the electric current in the oxide-type semiconductors now being used increases with increasing temperature. Some of the newer compound semiconductors offer new and interesting features for thermistor application.

With proper impurity content, InSb and InAs exhibit negative temperature coefficients of the order of 2 to 3% per °F (comparable with semiconductors used in currently available thermistors). However, the low resistivity of these new compounds (see Fig 1) allows the fabrication of thermistors in a much lower impedance range (0.001 to 100 ohms) than is possible with the oxide types.

Positive coefficients

Other semiconductors, such as PbSe, have large positive temperature coefficients of resistance (see Fig 1). The positive temperature coefficient is caused by a decrease in the mobility of the current-carrying electrons (and thus an increase in resistivity) with increasing temperature. The increase in resistivity is nearly proportional to the cube of the absolute temperature. Between 0 and 800 F the increase in resistivity is greater than 30-fold.

Changes with structure

Another useful phenomenon of some semiconductors, such as Ag_2S, is that at certain temperatures they undergo a change in crystal structure. This phase change induces a change in resistivity. To make optimum use of this phenomenon the semiconductor should have: 1) a large temperature coefficient of resistance over a relatively small temperature range, and 2) a phase change that takes place instantaneously and reversibly at a given temperature. Thus, the material is an insulator in one phase and a conductor in the other.

This characteristic can form the basis for automatic, low frequency contactless switches, self-resetting circuit breakers, and many types of simple electronic temperature control or indicating equipment.

The resistivity of Ag_2S at room temperature is about 10^6 ohm-cm, but at 360 F it drops to about 0.02 ohm-cm. Much of this resis-

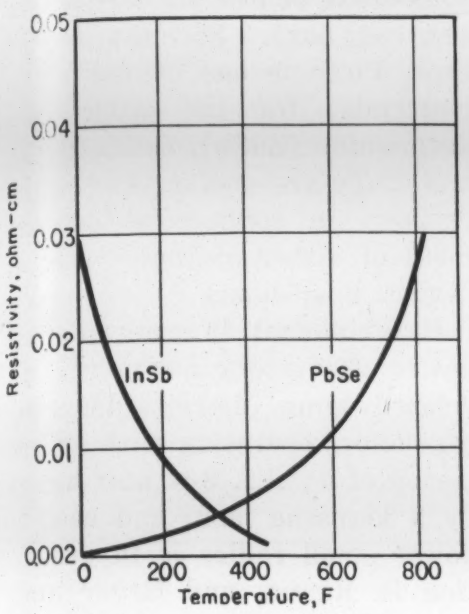


***Fig. 1**—Two semiconducting compounds of extremely low resistivity. Indium antimonide has a negative temperature coefficient of resistance; lead selenide a positive coefficient.*

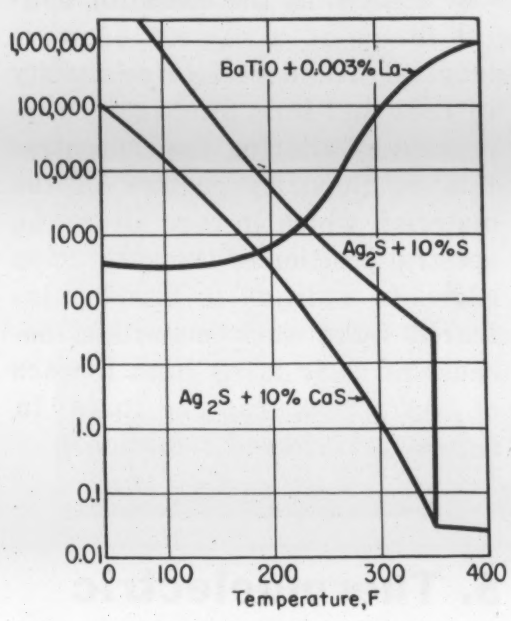


***Fig. 2**—Semiconductors having extremely large temperature coefficients of resistance. Curves also show effect of additives in altering phase change-induced resistance changes.*

tivity change occurs between 350 and 360 F, the temperature range over which phase change occurs. One disadvantage of Ag_2S is that part of the low temperature conductivity is ionic. If the material is used for direct currents, ionic transport will modify its electrical properties. Addition of impurities can reduce ionic conductivity and broaden the temperature range over which the phase change takes place. Fig 2 shows the effects of such additives.

Solid solutions of barium strontium titanate $BaTiO_3$, to which small amounts of certain impurities have been added, produce oxide thermistor systems that exhibit positive temperature coefficients of resistance as large as 8% per °F (see Fig 2). Increases in resistivity from 500 ohm-cm at 160 F to 10^6 ohm-cm at 300 F have been measured.

4. Optical devices

Two general optical phenomena common to semiconductors are useful in a variety of devices. They are 1) the photovoltaic effect, in which the semiconductor absorbs radiation and responds by emitting an electrical signal related to the intensity of the incident radiation, and 2) selective light transmission.

Photovoltaic effect

In a given material the photovoltaic effect depends to some extent on wave length. In particular, there is a cut-off point beyond which longer waves evoke no response. The location of this cut-off in the radiation spectrum is inversely proportional to the band separation in the semiconductor. As can be seen from the table of properties, the variety of band separation values is such that semiconductor materials are available to make detectors sensitive to radiation ranging from gamma rays through visible and out to the intermediate infrared.

The infrared range is particularly important for semiconductor photocells and optical components because of the recent interest by the military in the use of infrared for guidance, detection and control. At present, the important semiconductors in detectors for the infrared region of the spectrum are lead sulfide (PbS), lead telluride (PbTe), PbSe, InSb, and impurity-doped germanium and silicon. Other materials, such as mercury telluride (HgTe) and mercury selenide (HgSe), are also under investigation.

In the visible region of the spectrum, the photovoltaic effect has been used in photographic light meters for years. For such applications, efficiency of conversion is not critical.

For solar battery applications, however, conversion efficiency becomes critical. Compound semiconductors that seem most promising for this use are cadmium telluride (CdTe), InP, GaAs and AlSb. GaAs cells with solar radiation conversion efficiencies of over 6% have already been made; this compares with an efficiency of about 10% for cells using *p-n* junctions in silicon (maximum theoretical efficiency for this type of energy conversion is 20 to 25%). Cells operating at 10% efficiency generate about 100 w per sq yd of cell surface area on a sunny day.

The compounds should offer some slight benefits in efficiency of power output per unit of surface area. Since the differences in efficiency among the various semiconductors are expected to be small, the most important factor will probably be the economics of material and cell production.

For applications in the lower power ranges, such as automatic, light sensitive controls, important compounds are cadmium sulfide (CdS), cadmium selenide (CdSe), germanium and silicon.

At the other end of the spectrum, semiconducting compounds are also finding uses as detection elements for x-rays and various types of nuclear particles

Selective light transmission

In general, a semiconductor is transparent to light of wave length longer than the cut-off wave length of the material (i.e., the upper limit of wave length beyond which no photovoltaic effects are produced). Thus, semiconductors can serve as windows or filters for selected regions of the spectrum, or in some instances can be used as lenses.

For such applications, the important semiconductors are germanium, silicon, InSb, InAs and CdTe. The absorption edge in

***Thermoelectric devices** such as this experimental cooling unit (top) developed at Battelle make use of the Peltier effect. The unit makes use of bismuth telluride (cast ingots shown at bottom) to produce temperature differences of 85 °F.*

these and other semiconductors can be used as the basis for optical filters at a variety of wave lengths. The degree of selectivity of InSb and InAs filters can be increased by altering the concentration of impurity centers in the material, which in turn alters the spectral position of the absorption edge. In addition to filtering infrared light, such materials, because of their fairly high indexes of refraction, can be used in lenses for infrared radiation.

5. Thermoelectric devices

Thermoelectric devices are in the early stages of development. Semiconductors have been found to function well in devices making use of the Seebeck effect for generation of power, and in devices making use of the Peltier effect for cooling or heating (see accompanying box). For the former type, PbTe is one of the better materials; for the latter, zinc antimonide (ZnSb), CdSb, Bi_2Te_3 and PbTe are useful. The major problem in commercial development of either of these types of devices is efficiency.

Experimental thermoelectric power generators have been developed using intermetallic semiconductors operating with an efficiency of 7%. A 3-w unit heated by a kerosene lamp and used to power small radios is in production in Russia, and larger units are being tested.

In thermoelectric cooling, temperature drops of 40 to 50 °F have been reported using an intermetallic semiconductor—ZnSb, CdSb or Bi_2Te_3—as one element and a metal alloy as the other. Using both *p*- and *n*-type semiconductors (Bi_2Te_3 or PbTe) temperature drops of 70 to 90 °F have been obtained. With such performance, small cooling units are practical.

In utilizing the Peltier effect, the Russians would appear to be ahead of other nations. They have developed probably the first practical use for thermoelectric cooling, namely a hygrometer for recording air humidity. In early 1956 the Russians designed a Peltier refrigerator for household use having 4 cu ft volume. In other experiments using several stages of thermoelectric cooling, temperature drops of from 75 to 108 °F have been obtained by the Russians. In laboratories in this country single-stage temperature differences of about 122 °F can now be achieved.

Presently available thermoelectric materials are satisfactory for specialized uses such as small volume cooling, spot cooling of detectors, and various electronic components. For thermoelectric refrigerators to be as efficient as compressor systems in household and commercial applications, materials will have to be developed having figures of merit two to four times higher than now.

Seebeck and Peltier Effects

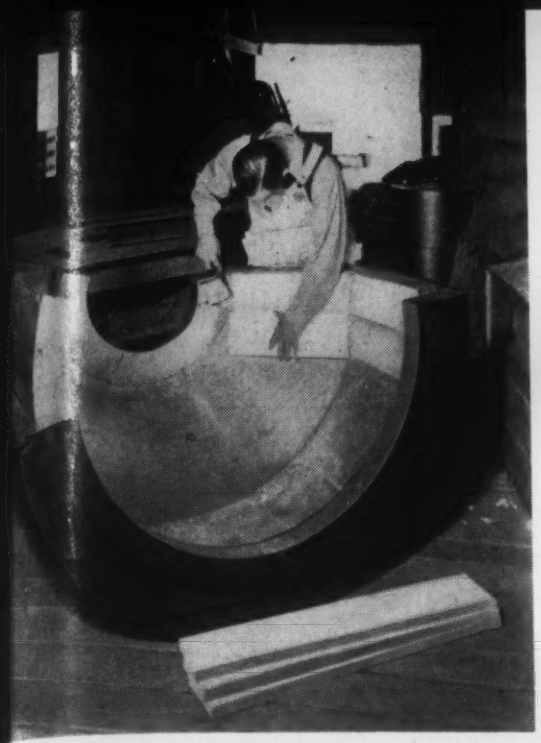
Thermoelectric devices make use of either the Seebeck or the Peltier effect. The Seebeck effect consists of the generation of an electromotive force when a junction of two dissimilar metals is heated. Thermocouples using dissimilar metal alloys, such as Chromel and Alumel, have been used for over a century for measuring temperature. However, this effect in metals is not practical for generation of electric power because of the low efficiency—less than 1%. More success has been obtained with compound semiconductors.

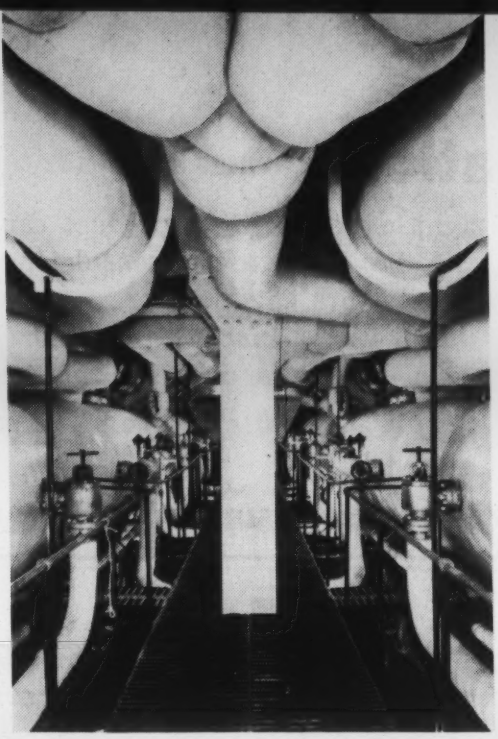
The Peltier effect consists of a heating or cooling effect when an electric current flows through a junction of dissimilar metals. For many years the magnitude of the effect observed experimentally with metals has been small—less than 1 °F. In 1950 a temperature drop of 18 °F was obtained using bismuth alloys. About this same time investigators began using semiconducting intermetallic compounds with greater success.

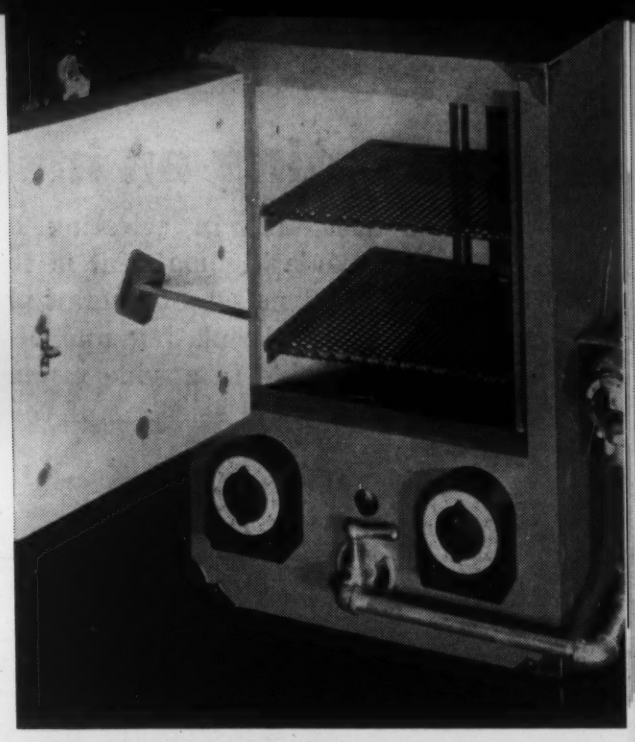
Materials requirements

Maximum useful temperature is the major point of difference in materials requirements for efficient thermoelectric power generation and for efficient cooling. For efficient thermoelectric generation of power, the hot junctions of the thermopile must operate at 1100 F or higher. In most thermoelectric cooling applications, hot junction temperatures would probably not exceed 150 F. Aside from this difference, requirements for efficient materials are essentially the same in both applications, i.e., low thermal conductivity (κ); low electrical resistivity (ρ); and high thermoelectric power (Q).

A figure of merit for a thermoelectric material can be defined as $Q^2T/\kappa\rho$, where T is junction temperature in °K. The maximum temperature difference attainable with a single-stage Peltier thermocouple is $Q^2Tc^2/2\kappa\rho$, where Tc is the temperature of the cold junction expressed in °K.

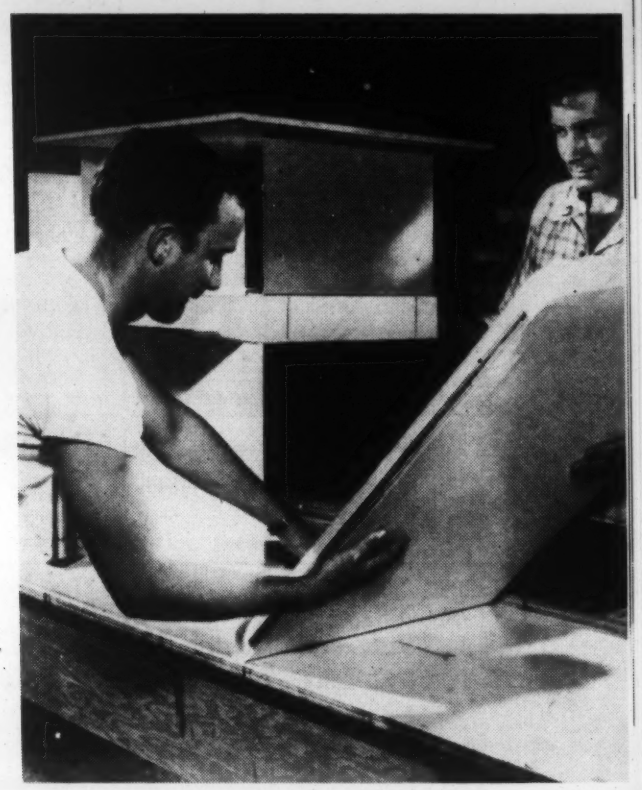


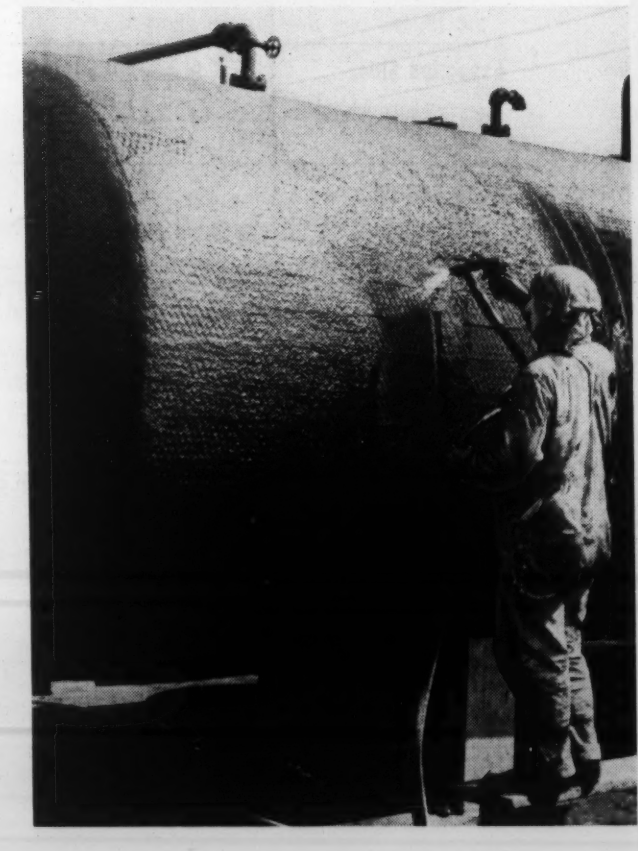




Thermal Insulation Materials

by Robert J. Fabian, *Associate Editor,*
Materials in Design Engineering





The term thermal insulations encompasses a wide range of materials, most of which are characterized by their high content of dead air spaces. No insulation can be used in all hot and cold applications. This article describes the principal insulations that are available, their properties, and the uses for which they are best suited.

Materials
in Design Engineering

Manual No. 147
March 1958

Selecting an insulation

The first step in selecting a thermal insulating material is to establish a firm set of operating requirements. Insulating materials are available in a wide range of properties, and selection of the right material for a product can only be made after considering such factors as:

Thermal efficiency — Just how much heat loss or gain can be tolerated in the product design? The ability of an insulation to control the passage of heat is measured by its thermal conductivity (in Btu/hr/sq ft/°F/in.) or "k" value. Insulations with a low k have good efficiency.

TABLE 1—HOW INSULATIONS COMPARE

Type ↓	Density, lb/cu ft	Ther Cond, Btu/hr/sq ft/°F/in.[a]	Maximum Operating Temperature, F	Principal Properties	Major Applications
Asbestos	Up to 65[b]	Laminated—0.36 at 100 F to 0.54 at 400 F; millboard (medium density)—0.76 at 100 F to 0.81 at 600 F; coatings—0.32 at 50 F to 0.53 at 400 F	300-1200[b,c]	Medium k; availability in wide range of forms; medium to high operating temperature limits; resistance to fire, some moisture, mold, bacteria, vermin	Good all-purpose insulation for heating applications. Heating and processing equipment, transportation equipment, housing, many specialized products
Mineral and Rock Wool	20 (block) 10 (blanket)	Blanket—0.36 at 200 F to 0.74 at 700 F; block—0.35 at 200 F to 0.67 at 1100 F	600-1900[b,c]	Low k; ability to withstand high and low temperatures; chemical inertness; moisture and fire resistant	Low temperature uses include cold water pipe lines and tanks, coolers and freezers, refrigerator trucks and storage rooms, air ducts, cold storage lockers. High temperature uses include ovens, hot water tanks, boilers, hot air ducts, heat exchangers, liquid pipe lines
85% Magnesia	12	0.35 at 100 F to 0.46 at 400 F	600	Low k; durability and structural stability; noncombustibility	Pipes, fittings and valves, headers, furnace walls, steam drums, ducts and flues, turbines, tanks, heaters, exchangers
Calcium Silicate	12	0.41 at 200 F to 0.60 at 600 F	1200-1800	Low k; high structural strength; durable	Generally same as 85% magnesia
Diatomaceous Silica	21-24	0.66 at 600 F to 0.74 at 1000 F	1500-2000[c]	Comparatively high k; resistance to high temperatures, moisture and many corrosive media; fire resistance; high structural strength in sheet form (asbestos-silica board)	Cylinders and blocks used to insulate high temperature pipe lines, furnaces, boiler walls, ovens, breechings. Sheet used for ship bulkheads, boiler breechings, ovens; and to protect structural steel
Expanded Silica	9	0.34 at 50 F to 0.41 at 200 F	350	Medium k; light weight; chemical inertness	Hot, cold and chilled water lines; low pressure steam lines; dual service heating and cooling systems
Silica Aerogel	5	0.11 at −150 F to 0.30 at +570 F	1300	Very low k; resistance to water vapor and fire	Can be used at extremely low temperatures as well as for some high temperature applications
Fibrous Glass	0.5-12	0.23-0.30 at 75 F	Up to 2000[c]	Low k; high sound absorption; availability in flexible and rigid forms; high tensile strength; resistance to moisture, fire, rotting, fungi and bacteria growth	Wide range of uses in appliances, transportation and industrial equipment, housing. Typical: ranges, ovens, refrigerators, aircraft, piping
Ceramic Fibers	3-12[b]	0.40 at 400 F	1000-2300	Excellent resistance to high temperatures; fire resistance; light weight; resistance to water, most chemicals	Large number of forms (e.g., bulk, textiles, castings, moldings and blocks) make for wide range of applications (see text)—largely high temperature
Cork	6.5-7.5	0.26 (board)[d]	About 200 F	Low k; light weight; high structural strength in rigid forms; resistance to moisture, decay, mold	Low temperature applications such as cold water and refrigerant lines, cold boxes, transportation equipment

[a] Thermal conductivity values vary more or less linearly from one temperature to another, and intermediate values between two temperatures can usually be determined by interpolating. For example, if a material has a k value of 0.20 at 0 F and 0.40 at 100 F, then its k value at 50 F would be 0.30.

Operating temperature — What is the maximum or minimum temperature that the insulation must tolerate? Some insulations can be used only up to 110 F (see Table 1 below); others are suitable for use beyond 2000 F.

Structural strength — Will the insulation be required to carry any load or be subject to damage? In many product designs this can be an important factor.

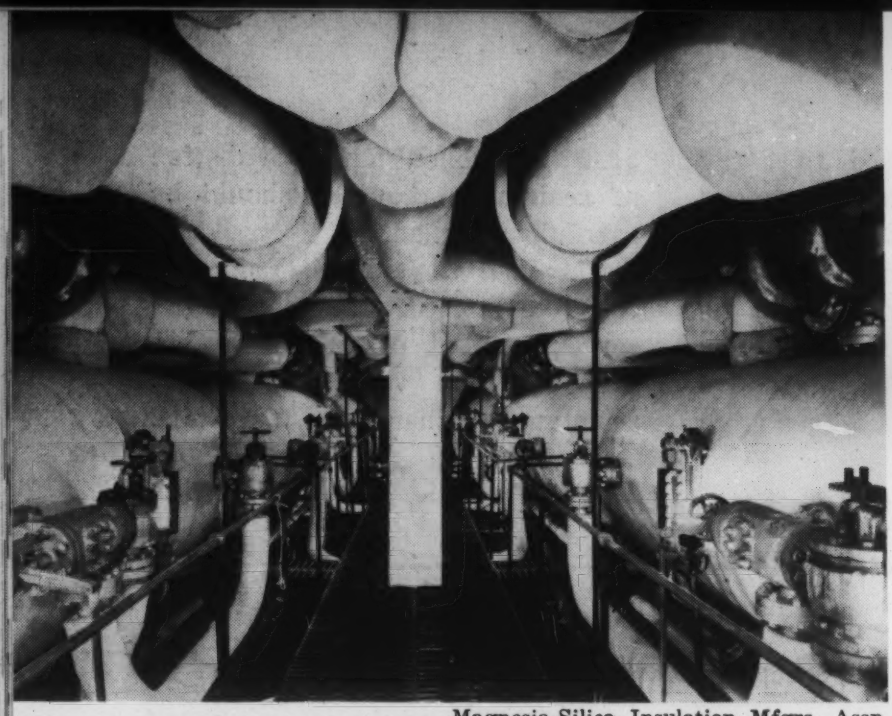
Moisture resistance — Will the insulation be used in a moisture laden atmosphere? The water resistance of insulation ranges from poor to excellent and the degree of resistance required should be carefully checked.

Chemical resistance—This factor, like moisture resistance, deserves careful consideration because of the varying chemical resistance of insulating materials.

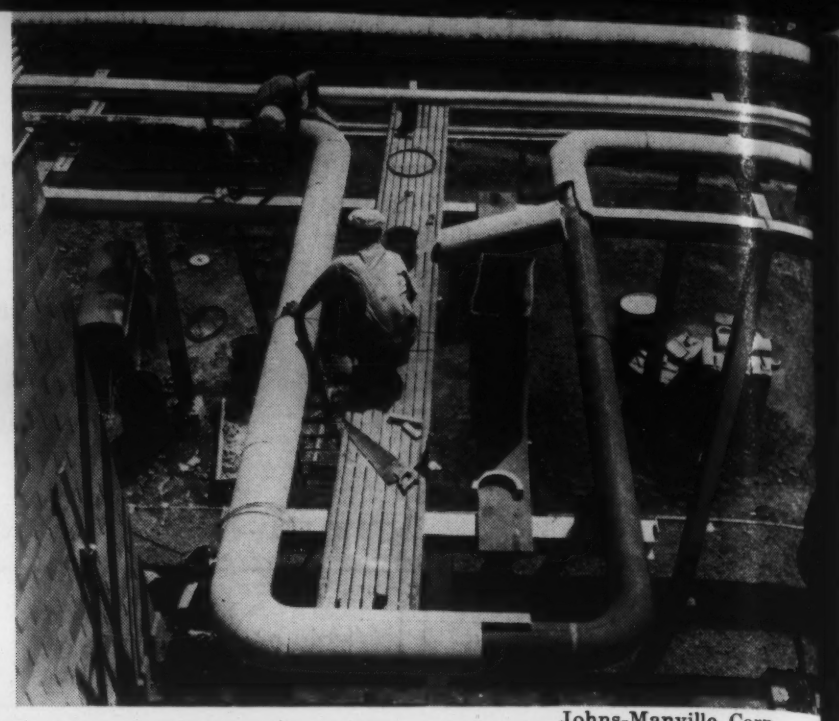
TABLE 1—HOW INSULATIONS COMPARE—continued

Type	Density, lb/cu ft	Ther Cond, Btu/hr/sq ft/°F/in.[a]	Maximum Operating Temperature, F	Principal Properties	Major Applications
Balsa Wood	5-14	0.27 (low density)[d]	350	Low to medium k; high structural strength	Structural insulations
Fiberboard	66	1.4 at 65 F	—	High k; high structural strength	Structural insulations
Softboard	1.5-50	0.24-0.40[d,e]	—	Low to medium k; high structural strength; good acoustical properties	Structural insulation for car, bus, truck and railroad car bodies; building insulation
Plywood	—	—	—	High k; high structural strength; good mar and fire resistance when metal-faced	Metal-faced structural insulation used largely for truck, trailer and railroad car bodies
Redwood Fibers	4½	0.17 at —120 F to 0.28 at 90 F	—	Low k; fair moisture resistance	Large freezers, coolers and controlled atmosphere equipment
Paper	—	—	300	Low cost; light weight; easy fabrication; poor structural strength	Low cost uses where strength, durability not too important
Organic Fibers and Felts	4 (felts)	0.21-0.27 (felts)	Up to 400[c]	Low k; light weight; flexibility; poor water resistance	Most light-duty applications
Foam Plastics	1.7-16[c]	0.20-0.29 at 100 F[c]	110-700[c]	Low k; very light weight; high strength-weight ratio (rigid types); resistance to water vapor and mold; conformability to odd shapes (foam-in-place types)	Low temperature types can be used in refrigerators, freezers and coolers. High temperature types can be used in special missile and aircraft applications where heat and weight are factors. Other types (see text) are available where special properties, such as good chemical resistance, are required
Cellular Rubber	8-18 (soft); 5-20 (hard)	0.27-0.30 (soft) 0.20-0.25 (hard)	250 (soft) 290 (hard)	Low k; availability in soft or hard forms in a variety of shapes; high strength-weight ratio (hard); resistance to moisture, vermin	Soft grades used principally as flexible insulation for refrigeration and air conditioning piping. Hard grades used in cold boxes, refrigerator rooms and trucks
Cellular Glass	8-10	0.22 at —100 F to 0.68 at 500 F	800	Low to medium k; good structural strength; resistance to moisture fire	Low temperature applications, including walls, ceilings and floors of cold storage rooms; refrigeration equipment and piping
Reflective Surfaces	—	Not a factor	About 700 F	High reflectance; good vapor barrier	Widely used in housing; also in some industrial and transportation equipment
Asphalt Coatings	—	0.5-0.7	275	High k; ability to supply good protection to primary insulation; resistance to moisture, weathering, many chemicals	Wide range of industrial and transportation equipment

[b]Depending on form. [c]Depending on composition. [d]Room temperature. [e]Depending on density.



Magnesia-Silica Insulation Mfgrs. Assn.



Johns-Manville Corp.

Piping *can be insulated with many different materials. Two of the most widely used materials are 85% magnesia (left) and calcium silicate (right).*

Sound absorption—In some applications a combination of thermal and sound insulation is required. Some insulations possess this combination; others have very poor sound insulation properties.

Other factors — Other factors that may have to be considered are: fire resistance, resistance to mold and bacteria decay, vermin resistance, and odor.

After the above requirements have been established, the next step is to evaluate each material individually. To help in this selection process, a master table (Table 1) has been prepared which summarizes the significant properties of each major insulation. This table is intended to serve as a rough selection guide. More specific information and recommendations can be obtained in the text.

Asbestos

Asbestos is one of the most widely known and used thermal insulations. The principal reasons for its popularity are its low thermal conductivity, good to excellent heat resistance, and incombustibility.

The name asbestos encompasses a broad group of materials which includes 30 or more minerals of fibrous crystalline structure. The six most important grades are chrysotile, crocidolite, amosite, anthophyllite, tremolite and antinolite. Chrysotile, the most widely used grade, is basically a hydrated silicate of magnesium occurring as veins in serpentine rock.

It is difficult to establish the properties of asbestos, since properties vary so widely with the form or shape of the material. The material is available in a considerable number of forms, most of which are made from chrysotile fibers. Typical of these forms, each of which will be discussed separately, are: 1) paper and rollboard, 2) air cell, 3) laminated or sponge, 4) millboard, 5) textiles, 6) coatings, and 7) cement.

Paper and rollboard

Asbestos papers mixed with a small amount of binder, such as a solution of sodium silicate, are used where a thin, flexible and fireproof insulation is required. They are available in flat or corrugated form, and will withstand temperatures up to about 350 F.

The 6-lb (0.015 in.) and 8-lb (0.019 in.) papers are used extensively in the manufacture of various pipe insulations. The 10-lb (0.022 in.) and 12-lb (0.027 in.) papers are used for wrapping hot air furnace pipes. Heavier rollboards up to ⅛ in. are used for lining stoves, ovens and gas ranges, and for making insulating gaskets and disks.

Air cell insulation

Air cell asbestos insulations are made up of alternate layers of flat and corrugated asbestos paper. The large amount of dead air space per inch of thickness results in high thermal efficiency, and the ribbed structure produces good mechanical strength.

Air cell insulations are available both in flat shapes and in tubular forms for pipe insulations. Pipe insulations are intended mainly for medium and low pressure steam and hot water lines, or for warm air pipes where temperatures do not exceed 300 F. Pipe covering is supplied either with a canvas jacket or with a smooth white paper finish.

Laminated or sponge insulation

This insulation is made up from laminated asbestos felts, ranging anywhere from 12 to 40 layers per in. of thickness. The thin air films that separate each layer of the material provide low thermal conductivity. Typical k values for a pipe insulation are 0.36 at 100 F and 0.54 at 400 F.

Scope of This Manual

Strictly speaking, all materials (even metals) act as thermal insulations to some extent. This manual encompasses those materials which are the most popular, and are most widely considered as thermal insulations, i.e., asbestos, mineral wool, plastics foams, etc. It does not encompass some of the nonmetallic materials less widely used as thermal insulations, such as high temperature plastics laminates, mica, solid rubber, most woods and special underground piping insulations; nor does it cover fire brick and combination insulation-refractories for high temperature furnaces and ovens. Ceramic coatings are not covered since they will be discussed at some length in a manual entitled, "Porcelain Enamels and Ceramic Coatings," to appear in the July issue.

Laminated insulations can be used at continuous operating temperatures up to 700 F. Because of their rugged structure, laminated pipe insulations are particularly recommended for applications where shock or vibration are encountered, or where rough usage or severe moisture conditions are expected. In addition to cylindrical sections, the material is available in block and sheet form.

Millboard

Asbestos millboard is designed to be used where a lightweight, rigid, fireproof insulation is required. It is particularly recommended for use in fire screens and partitions, and as a fireproof insulation for ceilings, walls, floors, elevator shafts, motion picture projector booths, ranges, stoves, grates, electric ovens, sterilizers and roasters.

Asbestos millboard is generally made of selected asbestos fibers combined with a suitable inorganic binder. Special grades are available that contain diatomaceous earth or cement for improved thermal and structural properties. Maximum operating temperature of the materials varies from 800 to 1000 F, depending on exact composition. Thermal conductivity also varies with composition and density. K values for a medium density grade (34-38 lb per cu ft) are: 0.76 at 100 F, 0.79 at 400 F, and 0.81 at 600 F.

Millboard is available in soft, medium, hard and special gasket stock. Medium grade is standard for most applications. Soft grade is used where some flexibility is required. The hard grade is stiff and is used where highest rigidity is required. Thicknesses vary from 1/32 to 1/2 in.

Textiles

The properties of asbestos fibers are particularly adaptable to the manufacture of textile insulations. Chrysotile fibers, in particular, possess high tensile strength, toughness and flexibility. As shown in Table 2, maximum operating temperature limits of textile insulations is a function of asbestos content, and limits vary from 400 to 900 F.

Some of the principal types of textile insulations and their applications are:

Lap and roving—largely used as electrical and thermal insulations for heater cords, fixture wires and other electrical conductors.

Cord—used as seals on high temperature corrugated metal gaskets, as valve stem packing, and as braided wall on steam hose.

Thread — largely used in the sewing of asbestos cloth and fabrics.

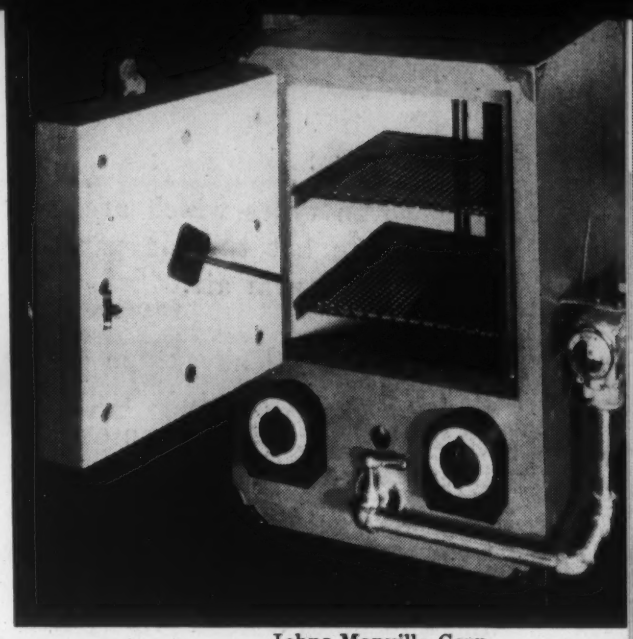
Wick—used as utility packing for hot lines and valves; as calking for retorts, ovens and furnaces; and as a core for high temperature packings.

Rope — used where material heavier than wick is required. Twisted rope is used as a seal between furnace doors and brickwork, as a cover for diesel engine exhaust lines, and as a core for high temperature packing. Braided rope is used to fill expansion joints in furnace brickwork, and as a gasket for doors and water gas generators.

Cloth—for fireproof fabrics, industrial furnace hoods, jackets for hot pipes, etc.

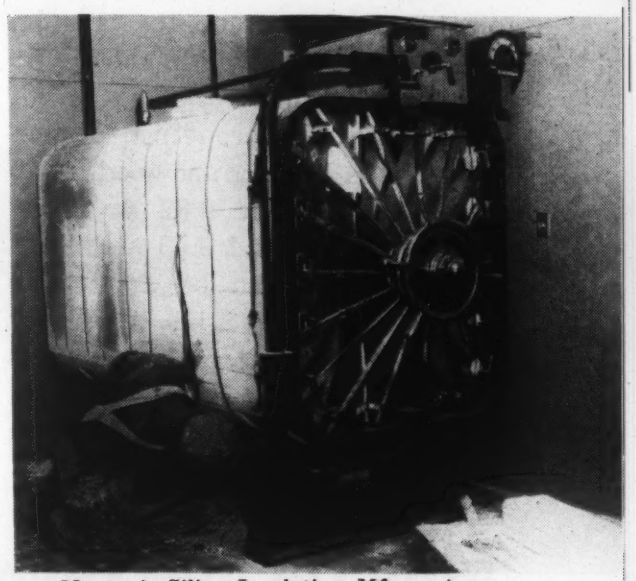
Tape—for hot pipes and as a part of packings and gaskets.

Tubing — available in braided



Johns-Manville Corp.

Gas-fired oven *insulated with double layer of asbestos-diatomaceous silica sheet operates continuously at 650 F without becoming hot on outside.*



Magnesia-Silica Insulation Mfgrs. Assn.

Autoclave *for pharmaceuticals is insulated with 85% magnesia block.*

TABLE 2—TEMPERATURE LIMITS OF ASBESTOS TEXTILE INSULATIONS

Grade	Asbestos Content, % by wt[a]	Highest Rec Svc Temp, F
Commercial	75-79	400
Underwriters'	80-84	450
Grade A	85-89	550
Grade AA	90-94	600
Grade AAA	95-98	750
Grade AAAA	99-100	900

[a]ASTM D299-52 T.

and woven types which are used to insulate hot tubular parts or to conduct warm air.

Coatings

The principal advantage of asbestos coatings is that they can be made to follow the contours of irregular surfaces. Two principal grades of asbestos coating insulations are available: 100% asbestos fiber with an inorganic binder; and a blend of asbestos fiber, bitumens and mineral filler.

The 100% asbestos grade is largely used in architectural applications and is sprayed on just like a paint. The material forms a continuous felt-like coating that completely blankets the surface and which can be finished with decorative paints.

Thermal and acoustical properties of the coating are good. Typical k values are 0.32 at 50 F, 0.39 at 200 F and 0.53 at 400 F. The material can be applied in thicknesses up to 2 in. Weight of a 1-in. coating varies from 13 to 16 oz per sq ft.

The asbestos-bitumens coating is largely used on outdoor industrial equipment, such as tanks, breechings and piping. The material possesses fair thermal efficiency and, because of its bitumens content, is waterproof and prevents corrosion of underlying metal. It is available in three consistencies for spray, brush or trowel application. In addition to being used directly on metal surfaces, the material can be applied over 85% magnesia, asbestos cement, mineral fibers and other insulations.

Cement

Various grades of asbestos cement are available for patching or finishing applications. Temperature limits of the materials vary from 500 to 1000 F, depending on composition. Cements are generally composed of a mixture of asbestos fibers and bonding agents such as clay, portland cement and water. The materials are mixed to mortar consistency and are applied with a trowel. They adhere well to metal surfaces and other insulating materials and have a smooth finish. They are particularly recommended for filling up joints in all types of insulation, for insulating small fittings, and as a finish coat over block insulation.

Amosite asbestos insulation

In addition to the chrysotile-type insulations described above, amosite asbestos fiber insulations are used to some extent, especially for high temperature piping. The upper operating temperature limit of amosite pipe insulations is about 1000 F, as compared to 700 F for the laminated chrysotile pipe insulations.

Aside from its higher temperature limit, amosite has roughly the same properties as chrysotile insulations. Thermal conductivity of the material varies linearly from 0.33 at 100 F to 0.72 at 900 F.

Amosite insulations are completely incombustible and will not warp, spall or crack after exposure to most solutions or vapors of acids or caustics.

Mineral and rock wool

In common with other inorganic insulations, mineral and rock wool insulations are chiefly distinguished for their: 1) ability to withstand high and low temperatures, 2) low k values, 3) chemical inertness, 4) fire resistance, and 5) serviceability. Upper temperature limit of the materials is somewhat higher than for asbestos and is roughly the same as for fibrous glass. The materials are produced by blowing steam through a molten mixture of rock and/or slag, or by spinning the molten mixture.

Properties of mineral wool and rock wool insulations are so similar that for the purposes of this discussion they can be considered as identical. As with other insulation materials, thermal conductivity (see Table 3) varies with density, form, and operating temperature. Upper temperature limits of mineral and rock wool insulations vary widely with form, ranging from as low as 350 F to as high as 1800 F.

Semi-rigid felts

Semi-rigid wool felts incorporating organic binders are recommended for low temperature applications and can also be used for heated equipment up to 400 F. They are characterized by high thermal efficiency and resistance to deterioration; they are also water repellent, chemically neutral (pH ranges from 7 to 8), nonsettling and noncombustible.

Principal low temperature uses include cold water pipelines and tanks, coolers and freezers, refrigerator trucks and storage rooms, air ducts and cold storage lockers. Principal low range heating applications include ovens, hot water tanks, cooking and heating appliances, small boilers and warm air ducts.

TABLE 3—TYPICAL PROPERTIES OF MINERAL WOOL INSULATIONS

Form ➡	Blanket	Block
Density, lb/cu ft	—	20
Maximum Svc Temp, F	1200	1900
Ther Cond, Btu/hr/sq ft/°F/in.		
200 F	0.36	0.35
500 F	0.57	0.44
700 F	0.74	0.51
1100 F	—	0.67
1600 F	—	0.91
Moisture Absorption	Nil	Nil
Fire Resistance	Incombustible	Incombustible

Blankets

Blanket insulations incorporating metal reinforcing fabrics are also available. These insulations, suitable for use up to 1200 F, consist of felted mineral wool secured between various combinations of metal fabrics, such as copper

Thermal Properties and Units: Some Basic Definitions

Heat transmission

Heat may be transmitted by:

Conduction—the passing of heat from one body to another by direct contact (e.g., food in a frying pan).

Convection—the transfer of heat by means of circulating air or liquids (e.g., a radiator).

Radiation—the transfer of heat from one body to another by the emission of radiant energy (e.g., solar heating).

* * *

Absorptivity is the fraction of heat impinging on a body which is absorbed.

Emissivity is the ratio of heat emitted by a body to the heat emitted by a black body at the same temperature.

Reflectivity is the fraction of heat impinging on a body which is reflected.

Thermal conductivity is the quantity of heat transmitted for a given time, area, unit temperature, and thickness. It is commonly measured in Btu/hr/sq ft/°F/in. In abbreviated terms this expression is known as the "k" factor.

Thermal insulating efficiency is the ratio of heat saved by an insulation to the heat that would be lost without insulation.

Units of heat

A *Btu* is the quantity of heat required to raise 1 lb of water 1 °F in temperature. A Btu equals 252 cal.

A *calorie* is the quantity of heat required to raise 1 gm of water 1 °C in temperature.

Latent heat and specific heat

Latent heat is the quantity of heat in Btu absorbed or given up by 1 lb of a substance during a change of state (there being no change of temperature).

Latent heat of fusion is the difference in total heat content between 1 lb of saturated solid and 1 lb of saturated liquid at the same temperature. For water the value is approximately 144 Btu per lb.

Latent heat of vaporization is the difference in total heat content between 1 lb of saturated liquid and 1 lb of saturated vapor at the same temperature. For water the value at atmospheric pressure and 212 F is 970.3 Btu per lb. Values for other pressures and temperatures are given in steam tables.

Specific heat is the quantity of heat required to raise a unit weight of a substance one degree in temperature. It is given as Btu/lb/°F or cal/gm/°C.

Heat equivalents

A *boiler horsepower* is equivalent to 33,475 Btu per hr.

A *ton of refrigeration* is equivalent to 12,000 Btu per hr.

Heat values of fuel

Coal—13,500 Btu per lb.
Oil—18,500 Btu per lb.
Gas (natural)—1000 Btu per cu ft.
Gas (artificial)—535 Btu per cu ft.

Temperature conversion

1 °F equals 0.555 °C.
F temperature equals 9/5 C temp +32.
C temperature equals 5/9 (F temp –32).

Courtesy of *Ruberoid Co.*

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bearing metal lath and galvanized wire netting. They are especially suited for large flat or curved surfaces. Typical high temperature applications include enameling, drying and core ovens, industrial washing machines, boilers and breechings, steam pipe lines, hot air ducts, stills and heat exchangers.

Blocks and cement

Block and cement type mineral wool insulations are available for operation up to 1800 F. In addition to high thermal efficiency, block insulations are characterized by their ability to follow irregular contours, and by their ability to be cut with a knife.

Because of their high operating temperature limit, block insulations are intended for use under the most severe operating conditions. Principal high temperature uses are in furnaces, annealing pits, melting tanks, boiler walls, glass and ceramic kilns and chilling pits.

Exceptional plasticity and adhesive properties make cement-type insulations adaptable for all types of heating equipment. They are especially suited for irregular surfaces where the application of other insulations would be difficult. They are prepared for application by mixing with water; because of their rust inhibitor content, they will not cause or accelerate corrosion when applied to ferrous surfaces.

85% magnesia

This material, discovered over 70 years ago, is one of the most popular industrial insulations in use today. It combines low conductivity and weight with high dimensional stability and strength, and resistance to moisture and fire.

The insulation is made from a relatively unstable form of carbonate of magnesia mixed with long asbestos fibers and water. After heating, the mixture is converted to a new compound consisting of not less than 85% basic hydrated carbonate of magnesia plus 10 to 15% of asbestos fibers. This compound has a high per-

Eagle-Picher Co.

Baldwin-Hill Co.

***Ducts** for hot and cold gases and air are often covered with mineral wool sheet for thermal and acoustical insulation.*

centage of dead air spaces which provide low thermal conductivity. A cubic foot of 85% magnesia contains only about 10% solid material by volume, the remaining volume consisting of dead air. These air spaces are microscopic and are uniformly distributed.

Properties

As shown in Table 4, the thermal conductivity of 85% magnesia ranges from 0.35 at 100 F to 0.46 at 400 F. These values are not as low as k values for other insulations, such as fibrous glass wool. Nevertheless, the material does have a number of other advantages that are noteworthy, the principal one being low cost.

The magnesia insulations are available in molded, block and cement forms, and are suitable for use on all hot surfaces at temperatures up to 600 F. At temperatures over 600 F, it is common practice to use the material in combination with an insulation possessing higher heat resistance. A popular combination insulation consists of an inner layer of diatomaceous silica plus an outer layer of 85% magnesia. The diatomaceous silica layer comes in direct contact with the hot body and has a temperature range up to 1600 F. It is applied in sufficient thickness to reduce the temperature at its outer surface to 600 F or lower.

Insulations made from 85% magnesia are structurally stable and do not shrink or distort after continued exposure to heat. Snug fits and tight joints are retained after long usage. The material is durable and can withstand an appreciable amount of compression and mechanical abuse.

In normal operation, 85% magnesia insulations possess good resistance to moisture. Since 85% magnesia is entirely mineral, it will not burn or support combustion. Tests have shown that even when exposed to 2000 F the insulation remains intact and provides protection.

Applications

Primarily used to insulate industrial equipment, 85% magnesia is not ordinarily used to insulate appliances or transportation equipment. Principal industrial applications of the material are piping, fittings and valves, headers, furnace walls, steam drums and drum heads, ducts and flues, turbines, tanks, and heaters and exchangers.

Pipe insulations are usually supplied in semicylindrical sections or curved segments, 3 ft long, to fit standard steel or wrought iron pipe and copper tubing. Flat equipment is usually insulated with block-type insulations which are firmly secured by metal straps, pins, and/or a strong insulating cement.

TABLE 4—TYPICAL PROPERTIES OF 85% MAGNESIA

Ther Cond, Btu/hr/sq ft/°F/in.	
100 F	0.42
200 F	0.45
300 F	0.48
400 F	0.52
Max Service Temperature, F	600
Density, lb/cu ft	12.5-13.5
Modulus of Rupture, psi	45-55
Compressive Strength (to produce 5% compr), psi	65-75
Linear Shrinkage (after 24 hr at 600 F), %	1-2

Finishes for magnesia

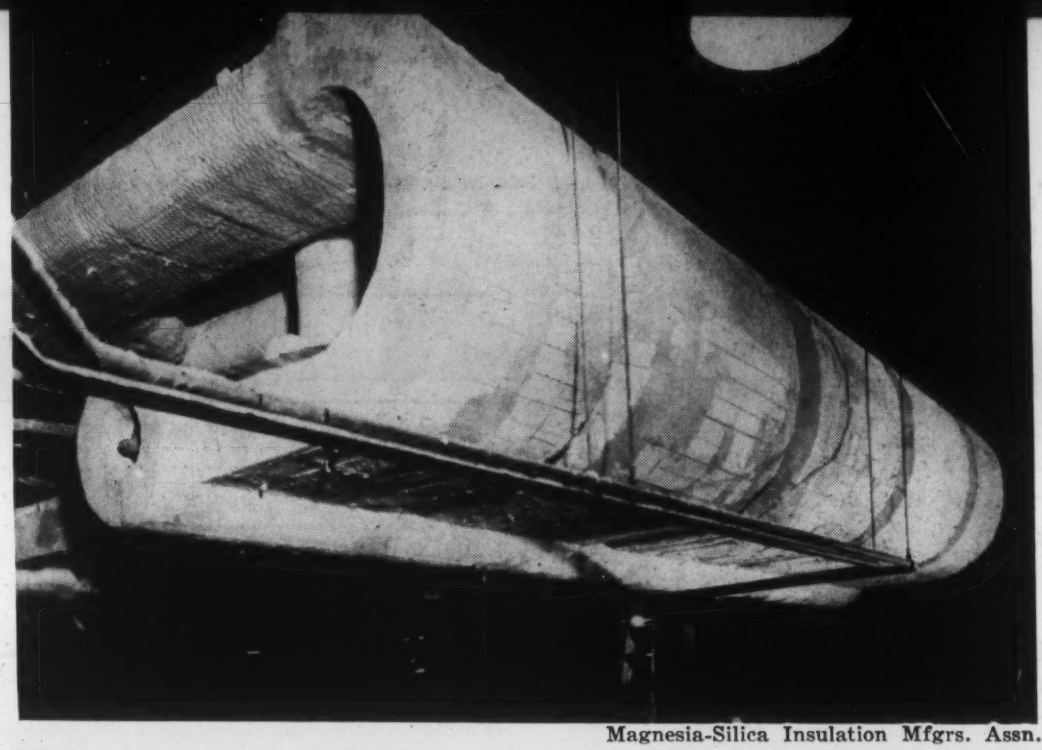
Some kind of finish or jacket is usually installed over 85% magnesia to protect it against moisture, chemicals, weathering or mechanical damage, and to improve appearance. Polyvinyl acetate coatings have become very popular in the past few years. A lightweight, factory-installed jacket is used for many indoor pipe applications. Where greater protection is required, this jacket can be removed and a heavier canvas covering substituted. At points where the equipment is adjacent to hot metal surfaces and the canvas is liable to burn insulating cement or asbestos cloth is used.

An asbestos cement finish is frequently used on small, irregularly shaped equipment. The cement is applied directly to the magnesia surface and may be mixed with portland cement for an extra hard finish. On large equipment such as ducts a wire mesh is frequently used under the

cement for reinforcement.

Pipe insulation that requires protection against weathering may be finished with asbestos felt that has been saturated and coated with asphalt. For weatherproofing uneven surfaces where a felt finish is impractical (as on bends, flanges, valves and fittings), a plastic finish consisting of asbestos fiber and an asphalt compound is used.

Other finishes include sheet steel jackets for use where there is danger of mechanical damage, and asbestos cloth for fire resistance and high heat resistance.



Magnesia-Silica Insulation Mfgrs. Assn.

Power generation equipment *such as this downtake header is frequently insulated with 85% magnesia.*

Calcium silicate

The structural strength and operating temperature limits of calcium silicate are somewhat higher than those of 85% magnesia. The material is intended principally for high pressure, high temperature steam and process pipe lines and has a maximum service temperature of 1200 to 1800 F, depending on composition. The insulation is made up of hydrous calcium silicate reinforced with asbestos fibers.

Thermal conductivity of calcium silicate is about the same as for asbestos and 85% magnesia, varying linearly from 0.41 at 200 F to 0.60 at 600 F. Density is about 12 lb per cu ft. The material resists most acids and alkalis, as well as moisture, and is particularly suited for underground installation because of its good wet strength.

Calcium silicate insulations are primarily made in block and cylindrical pipe form. They can be applied on pipe lines and equipment in either single or double layers and, in many applications, are used as a high temperature layer under 85% magnesia.

Magnesia-Silica Insulation Mfgrs. Assn.

Heat exchanger *cover head is insulated with 85% magnesia.*

Diatomaceous silica

Diatomaceous silica (occasionally called diatomaceous earth) insulations are quite versatile and are available in a wide range of compositions and forms. Three of the principal compositions are described here:

1. One of the principal compositions is essentially granular. It has unusually high heat resistance and is used for insulating and fireproof cements, insulating concrete and insulating fill for temperatures up to 2000 F.

2. Another composition, with a somewhat wider range of applications, consists of specially heat treated diatomaceous silicas blended with carefully graded long asbestos fibers, magnesia carbonate and binders. This composition is molded into cylindrical and block forms and is widely used as an insulation for high temperature pipe lines and equipment such as furnaces, boiler walls, ovens and breechings.

The material has high thermal efficiency and sufficient strength to withstand vibration and normal service abuse. It is durable, shock resistant, and has high dimensional stability. The material can be used up to 1500-1900 F; however, above 600 F it is common to use an outer layer of 85% magnesia with the material, choosing thickness of the layers so that the temperature at their interface is 600 F or less.

3. Still another composition is a calcium silicate type made from diatomaceous silica plus asbestos fibers and an inorganic binder (see "New Structural Insulating Material," MATERIALS & METHODS, Dec '54, p 96). This structural insulating material is produced in sheet form and combines excellent thermal properties with good strength and light weight.

It is produced in three different grades and densities. Some of the properties of these grades are given in Table 5. The material can be used at temperatures up to 900 F, and thermal conductivity

compares favorably with that of 85% magnesia. Transverse strength varies from 550 to 1500 psi for the three grades. Hardness of the general purpose grade is comparable to that of yellow pine. The material will not disintegrate upon immersion in water, and resists attack by many corrosive materials, including some liquid metals. Principal applications are ship bulkheads, power plant boiler breechings, ovens, and protection of structural steel in processing plants.

TABLE 5—TYPICAL PROPERTIES OF DIATOMACEOUS SILICA-ASBESTOS FIBER SHEET

Density[a] →	21-25	34-38	60-70
Thermal Conductivity, Btu/hr/sq ft/°F/in.			
100 F	0.55	0.76	1.50
400 F	0.60	0.79	1.68
600 F	0.63	0.81	1.80
Maximum Operating Temperature, F	900	900	800
Coef of Ther Exp, 10^{-6} per °F	2.0[b]	1.3[c]	2.6[c]
Modulus of Elasticity, psi	1.5×10^5	4.0×10^5	7.0×10^5
Transverse Strength, psi	550	900	1500

[a]In lb per cu ft.
[b]To 200 F; shrinkage starts above this temp.
[c]To 250 F; shrinkage starts above this temp.

Other silicas

In addition to the above compositions, two other silica insulations are available for specialized applications: expanded silica and silica aerogel.

Expanded silica

This material is made from a chemically inert silica aggregate containing a myriad of small water particles. When heat is applied, the water is vaporized, exploding the silica and causing it to expand to many times its original volume. The expansion forms a lightweight inorganic cellular structure consisting of many minute voids and sealed cells containing air under partial vacuum.

Because of its porous structure, expanded silica has both low density and low thermal conductivity. Density in molded form is about 9 lb per cu ft; k values range from 0.34 at 50 F to 0.41 at 200 F. The insulation can be used at temperatures from 35 to 300 F.

Expanded silica insulation is largely used in molded pipe form with a protective coating or jacket. Principal applications are for hot, cold and chilled water lines, low pressure steam lines, and dual service heating and cooling systems.

Silica aerogel

This insulation consists of a chemically produced skeleton of silica. The material is distinguished principally for its very light weight (5 lb per cu ft) and its very low thermal conductivity. Conductivity ranges from a low value of 0.11 at –150 F to only 0.30 at +570 F. The insulation has proved quite effective at temperatures as low as –320 F and will withstand temperatures as high as 1300 F without deteriorating. It is also unaffected by atmospheric water vapor after an initial increase of moisture vapor content to about 3 to 4%. The material absorbs water readily and loses its insulation value at water contents in excess of 30% by weight.

Silica aerogel is easily poured, sucked or blown into a retaining jacket. In refrigeration equipment the insulation is commonly applied by pouring it through a small opening in the back of the unit. To insure uniform distribution, the unit is slowly vibrated during the filling operation.

Fibrous glass

Fibrous glass insulations can be used effectively at both low and high temperatures. Principal advantages of the material include: 1) low thermal conductivity, 2) high sound absorption, 3) availability in flexible and rigid forms, 4) high tensile strength, 5) lack of odor, and 6) resistance to moisture, fire, rotting, and fungi and bacteria growth.

Glass fibers are produced by steam or air jets which impinge upon, and break up, molten streams of glass. The type of fibers produced depends upon the pressure of the steam or air and the temperature and viscosity of the molten glass. As pressure and temperature are increased, the action changes from the smooth attenuation of long, uniform textile grade fibers to a violent action which draws the streams out turbulently in many directions and produces shorter, finer fibers. After the fibers are blown they form a tangled mass whose properties are determined by such factors as size and length of the fibers, density of packing and the type of lubricant or binder used.

Properties

The excellent insulating properties of fibrous glass are due to the large pockets of air between the fibers. These air pockets take up considerable volume. For example, in the case of glass wool packed to a density of 6 lb per cu ft, the fibers occupy only about 4% of

TABLE 6—TYPICAL PROPERTIES AND APPLICATIONS OF FIBROUS GLASS INSULATION

Type	Fiber Diameter, in.	Binder	Density, lb/cu ft	Ther Cond (75 F), Btu/hr/sq ft/°F/in.	Max Temperature Limit, F[a]	Major Applications
Unbonded Quartz Fibers	0.000029	None	3.0	0.24 (100 F)	2000	Very high temperature uses
Unbonded Wool (white)	0.0005	Oil only	1.5 up (3.0 std)	0.27-0.30	1000	Heating equipment, appliances
Bonded Wool (molded)	0.00038	Phenolic resin	—	0.25 (100 F)	450	Low temperature and low pressure heated pipe
Bonded Wool (fine fiber)	0.00004	Phenolic plus high temperature resins	0.6	0.23	600	Aircraft
	0.00012	Phenolic plus high temperature resins	0.75-2.0	0.22-0.27	600	Wrap-on pipe insulations
		Phenolic resin	0.75-2.0	0.22-0.27	450	General purpose
		Phenolic resin plus silicone oil	0.3-0.5	—	—	Seat cushions, clothing interlinings
	0.00017	Phenolic resin	0.75-2.00	0.24-0.29	450	Railroad cars, trucks, furnaces
Bonded Wool	0.00034	Phenolic resin	1.5-3.75	0.23-0.26	450	Appliances
	0.0005	Phenolic resin	2.0-3.75	0.25-0.28	450	Appliances
	0.0006	Phenolic plus high temperature resins	6.0	0.24	600	Ducts, fire barriers
		Phenolic resin	2.0-12.0	0.26-0.29	450	General purpose. Fabricated forms: rolls, batts, blocks, boards, metal mesh blankets, duct insulations, pouring wool

[a]Maximum temperature of surface in contact with insulation under the most favorable conditions. Organic binders and lubricants begin to oxidize at 275 F; loss depends upon amount present, access to oxygen, and thickness and density of insulation. There is no low temperature limit.

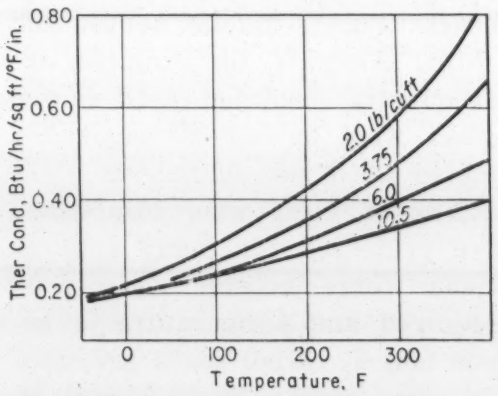
the volume, the remaining 96% being air. At a given temperature thermal conductivity (see Fig 1) is a function of fiber diameter and orientation, density, and the type and amount of bonding agent, if used. Bonding agents consisting of phenolic or high temperature resins are usually used with the semi-rigid and rigid types of insulation.

Fibrous glass insulations are not affected by low temperatures and have been used satisfactorily as low as –350 F.

The upper temperature limit of *unbonded* fibrous glass ranges as high as 2000 F, depending on glass composition. Fibers based on borosilicate glass are generally limited to operating temperatures of 900 to 1100 F. Fibers based on 96% silica are capable of operating at 1830 F, and fibers made from 98% pure quartz can be used to 2000 F.

The temperature limit of *bonded* fibrous glass insulations is limited by the bond used and the type of application. As shown in Table 6, temperature limits vary from 450 to 600 F.

The low capillarity of fibrous glass helps to keep it dry when it comes in contact with moisture. The material will not deteriorate even if it becomes wet. Nevertheless, despite this resistance to moisture, care must be taken to prevent the condensation and freezing of moisture in the body of the insulation. Condensation can be prevented by using a vapor barrier such as asphalt impregnated paper, an asphaltic coating or metal foil. For cold storage rooms or refrigeration pipes, the diffusion rate of this barrier



***Glass fiber** thermal conductivity at various densities and temperatures.*

should not be greater than 0.02 perm (1 perm = 1 grain of water passed per hr per sq ft at a pressure differential of 1 in. Hg).

Forms and applications

In addition to building applications, fibrous glass is widely used in consumer and commercial appliances, and in transportation

Armstrong Cork Co.

***Mobile homes** are covered with glass fiber insulation because of material's light weight, ease of handling and thermal and acoustical properties.*

and industrial equipment.

Unbonded insulations are available in a number of forms and can be cut and shaped to insulate curved or irregularly shaped surfaces. Unbonded batts are frequently used in heating appliances such as range ovens, roasters, dryers and water heaters. During assembly the batts are compressed by the walls of the appliance to a final density of 3 lb per cu ft.

Because of its light weight and resistance to fire, fibrous glass is widely used for insulating transportation equipment such as aircraft, trucks, mobile homes and ships. Aircraft, for example, are frequently insulated with a fine glass wool having a density of 0.5 to 0.6 lb per cu ft.

Bonded glass wool insulations are preferred for many applications where greater rigidity is required and temperature is below 600 F. Wool batts are used in some water heaters and in domestic furnaces. The batts are held in place by adhesives or metal fasteners and may be lined with aluminum foil.

Bonded fibrous glass board faced on one side with glass cloth is used on U. S. Navy ships. This material has a density of 9 lb per cu ft and is fastened to bulkheads by means of large headed pins which are pushed through the insulation and resistance welded in place. Similar materials with a lower density (3¼ lb per cu ft) are also used on bulkheads.

Pre-cut bonded wool is used in doors and walls of refrigerators, freezers and coolers. In such applications the metal outer wall functions as an excellent vapor barrier, and the inner wall is frequently vented to allow water vapor to escape from the insulation. Insulation densities are usually 2 or 2½ lb per cu ft.

Blanket insulations are frequently used for covering such equipment as boilers, cylinders, piping, ovens and tanks and tank cars. Blankets, faced on one or both sides with a metal mesh, may contain either unbonded wool with a density of 6 lb per cu ft or bonded wool with a density of 4¼ lb per cu ft. The bonded wool insulation, though stiffer than the unbonded material, can be bent readily over curved surfaces.

Block insulations, fabricated from high density bonded wools, are sometimes used instead of blankets for applications below 450 F. Blocks with a density of 9 lb per cu ft have a flexural strength of 90 psi and are easily cut to special shapes.

Preformed insulations made of bonded glass are available for piping at temperatures up to 450 F. These materials are supplied in split cylindrical form and are covered with a canvas cloth. Density of the wool is about 7½ lb per cu ft. For temperatures above 600 F a blanket type of unbonded wool is used.

Finishes

Fibrous glass insulations can be obtained with a number of surface finishes or facings, depending on the type of application. Typical finishes are: asphalt; glass yarn-reinforced paper laminated with asphalt; asphalt-laminated kraft paper reinforced with glass yarn scrim; flame resistant, reinforced paper and foil; aluminum foil; and aluminum-pigmented vinyl film. Neoprene and vinyl coatings (not vapor barriers) are also available to minimize air erosion in duct liner application.

Aluminum silicate

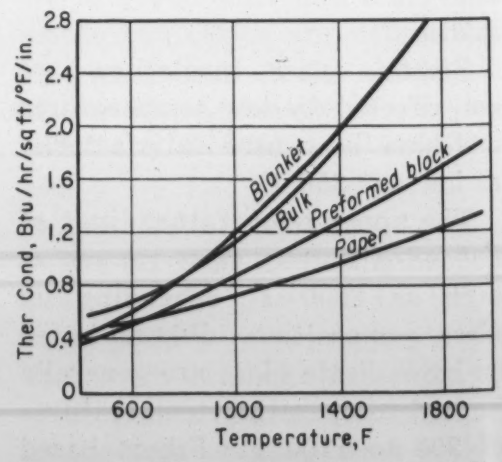
Aluminum silicate fibers were originally developed as protective insulations for jet engines. In recent years, however, many prefabricated forms have been developed, and the materials have become important for many other applications requiring high temperature resistance, light weight, strength and comparatively low thermal conductivity.

Properties

Aluminum silicate fibers are primarily intended for use at temperatures from 1000 to 2300 F. This temperature range falls between those of conventional inorganic fibers (such as glass, mineral wool and asbestos) and insulating refractories.

Aluminum silicate fiber has a melting point above 3000 F, and a maximum usable temperature of 2300 F. When exposed to temperatures over 2000 F for long periods the material undergoes devitrification. This phase change produces increased brittleness, lower tensile strength and abrasion resistance, and some indication of shrinkage.

As shown in Fig 2, thermal conductivity of the material depends to a large extent on the form in which it is produced. At 1400 F, for example, k values



***Ceramic fiber** thermal conductivity at various temperatures.*

range from 1.0 for the paper form to 2.0 for the blanket or felt form.

Density also varies widely with form. In bulk form, density of the material is about 4.5 lb per cu ft. In felted form the material weighs from 3 to 12 lb per cu ft.

Applications

Aluminum silicate fibers are produced in a variety of shapes for specific end uses. Some of the principal forms and applications are:

Bulk—Used primarily as high temperature insulation for furnace hot topping, heating element cushions and jet engines; and as an expansion joint packing in kilns to reduce heat losses and maintain uniform temperatures.

Textiles—Several types of high temperature textiles have been developed, including blankets, roving, yarn, rope, tape and broad woven goods. Aluminum silicate blankets are used in furnace tops, sidewalls and ducts, on turbine exhaust lines, and on superheated steam piping. Combinations of aluminum silicate blankets with glass fiber or asbestos materials are also used, the blanket reducing temperatures to a safe range for the glass or asbestos.

Cast forms—A castable aluminum silicate fiber utilizing high temperature binders has been developed. In addition to drying lids and pressure vessel linings, cast forms have been used experimentally on boiler access doors, and as incinerator linings, duct insulations and induction furnace shielding.

Moldings—Moldings have essentially the same fiber and binder composition as cast forms. Typical applications investigated include: combustion chamber liners, baffles and flame deflectors, and furnace and oven liners.

Blocks—Preformed blocks, usable up to 2300 F, are made from short staple aluminum silicate fibers plus suitable fillers and binders. These forms are actually refractory insulations and are used to lower wall temperatures in industrial furnaces, kilns and combustion chambers.

Wood products

Wood has long been popular as an insulation material for a number of important reasons. In its various forms wood combines low conductivity with high structural strength, low cost and easy fabrication. Some of the principal types of wood insulations in use today are: 1) cork, 2) balsa, 3) fiberboard, 4) softboard, 5) plywood, 6) redwood fibers, and 7) paper.

Cork

In general, cork insulations are made from granules of pure cork which are compressed and baked. Baking releases natural resins in the material which act as an adhesive and bind the granules together. The material is available in three principal types: board, semi-flexible segmented pipe insulation, and molded insulation.

Board insulations, intended primarily for low temperature applications, are available plain or with a protective facing consisting of an asphalt-mastic coating on one or both sides. Thermal conductivity is low—about 0.26 at 60 F. Allowable continuous operating temperatures range from –300 to +200 F.

Board insulations are principally noted for their high structural strength. Modulus of rupture of the material is about 21 psi, and solid walls have been erected to a height of 14 ft without support. Density ranges from 6.6 to 7.8 lb per cu ft.

The natural cellular structure of the cork eliminates capillarity and effectively seals out moisture. In addition to its moisture resistance, the cork is quite resistant to decay and mold, is free from contaminating odors, and provides no harboring place for vermin.

Semi-flexible insulations are made from precision-cut segments of cork which are adhered to a flexible backing of asbestos paper and aluminum foil laminate. The asbestos paper backing provides a fire resistant finish; the aluminum foil acts as a vapor seal. The insulations are used in various thicknesses which are calculated to prevent condensation when used indoors under normal design conditions and within a recommended temperature range.

Molded insulations are produced by compressing the cork in molds of proper size and shape for various sizes of pipes and fittings. After baking, the sections are machined to accurate size and finished inside and out with an airtight, moistureproof asphalt mastic compound.

Molded insulations have a density of about 10 lb per cu ft and are available in three types:

1. *Light duty* cork coverings, averaging about 1½ in. thick, are intended for use on refrigerated water or other cold lines operating at temperatures above 30 F.

2. *Medium duty* cork coverings, about 2½ in. thick, are used principally on brine, ammonia, carbon dioxide and similar pipe lines from 0 to 30 F, or where the maximum difference between the refrigerant and the surrounding air is less than 100 °F.

3. *Heavy duty* cork coverings, up to 4.2 in. thick, are intended for cold lines operating from 0 to –25 F, or where surrounding temperatures are unusually high, as in boiler rooms or adjacent to steam lines. Still thicker coverings are available for temperatures down to –300 F.

Maximum service temperature of all molded cork insulations is 200 F. Thermal conductivity is 0.26 at 60 F and 0.27 at 90 F (mean temperature). Coefficient of expansion is 5.0×10^{-5} per °F.

Balsa

The principal advantage of balsa wood as an insulating material is that it combines low conductivity with comparatively high structural strength. Thermal conductivity of balsa wood at low densities (see Table 7) compares favorably with that of other insulating materials. The good thermal properties of the material derive from its cellular structure and pockets of entrapped air.

TABLE 7—TYPICAL PROPERTIES OF BALSA WOOD

Density[a] ➡	5	9	14
Ther Cond, Btu/hr/sq ft/°F/in.[b]	0.287	0.385	0.508
Compression Properties (perp to grain), psi			
Stress at Proportional Limit	300	1050	1900
Max Crushing Strength	550	1440	2600
Modulus of Elasticity	210,000	580,000	1,000,000
Compression Properties (perp to grain), psi			
Stress at Proportional Limit[c]	40-70	80-115	130-180
Bending Properties, psi			
Stress at Proportional Limit	600	1350	2275
Modulus of Rupture	1050	2375	4000
Modulus of Elasticity	210,000	485,000	825,000
Tensile Strength (perp to grain), psi[c]	65-100	100-145	145-205
Shear Strength, psi[c]	130-145	245-290	385-475
Impact Strength (perp to grain), in. lb[c]	90	210-235	355-420

[a]In lb per cu ft.
[b]$K = S(1.39 + 0.28M) + 0.165$; where S = specific gravity and M = moisture content (assumed to be 5%).
[c]Values depend on direction of loading.

Because of its structural strength, balsa can be used without highly conductive stiffening members. These stiffening members, commonly used with non-structural insulations, can account for over half the total heat losses of even the best designed panel insulations.

A significant use of balsa insulations in recent years has been as a core material in reinforced plastics tanks. These tanks, usually used for milk trucks, have proved superior in some respects to conventional metal tanks. A 2-in. thick sheet of balsa forms the heart of the combination insulation-structure; it is combined with a glass cloth-reinforced plastics shell and a thin stainless steel lining. In addition to its good insulating properties, the structure has high strength, resists weathering, and is easy to repair.

Balsa insulations are also capable of being used at comparatively high temperatures. Unprotected insulations are capable of operating at temperatures up to 350 F with little impairment of physical properties. At temperatures above this value, oxidation begins to occur and physical properties drop off. Higher temperatures can be tolerated, of course, if the balsa is used as a core material and is suitably protected from exposure.

Fiberboard

Fiberboard insulations made from fibers of woods such as southern pine are ideally suited as structural insulations. They are particularly desirable for use in conjunction with non-load-bearing types of insulation and are used in such applications as: supporting strips in cold cabinet bottoms, mounting boards under mechanical units, and structural insulations to reduce the weight of framing members.

Thermal conductivity of the materials is about 1.4 at a mean temperature of 65 F. Density is about 66 lb per cu ft.

Fiberboard insulations have a high degree of moisture resistance because of an asphalt impregnant which coats each fiber with a waterproof film. Tests show only 2.2% water absorption by volume. The materials have high loading capacity and can be fabricated into complicated shapes.

Softboard

Softboard materials in a number of densities are widely used as thermal and acoustical insulations. The method used for producing the materials is similar to that used for making thick papers, i.e., mechanically felting wood or bagasse fibers into mat.

Softboards can be divided into three principal classes: semi-rigid, rigid and intermediate density. Semi-rigid types have a density of 1.5 to 9 lb per cu ft and k values of 0.24 to 0.27. Rigid types, in densities of 9 to 25 lb per cu ft, have thermal conductivity values ranging from 0.27 to 0.40.

Density of the intermediate types varies from 25 to 50 lb per cu ft. Thermal conductivity values are comparatively high and range from 0.40 to 0.80. Intermediate density softboards, however, possess relatively good mechanical strength. Modulus of rupture varies from 400 to 4000 psi, and modulus of elasticity in bending varies from 90,000 to 700,000 psi.

Semi-rigid softboard has the lowest density and thermal conductivity of all wood composition boards. It is used to insulate car, bus, railroad and truck bodies; refrigerators; and other equipment where loose insulation would be undesirable because of vibration. Rigid and intermediate density softboards are used primarily as building insulations. Although the rigid type has better insulating properties, the intermediate density material is more resistant to scuffing and marring.

Plywood

Plywood's high thermal conductivity, compared to that of some of the more cellular or fibrous wood materials, is offset by its high structural strength and its ability to withstand abuse. In some industrial applications plywood is used without any protective facing. However, in many applications the range of the material is extended by providing it with a more durable facing, usually a metal.

Some of the common metal facings that are bonded to plywood are: aluminum, stainless steel, porcelain enameled steel and zinc coated steel. (In addition to plywood, these metal facings can also be bonded to many other insulations such as hardboard, balsa wood, asbestos-diatomaceous silica board, cellular rubber and polystyrene foam.)

One of the principal applications for metal-faced plywood is transportation equipment. When used

in truck, trailer and railway bodies, such insulation provides fair thermal efficiency with comparatively low weight, ease of assembly, mar and heat resistance, and some degree of sound and vibration absorption.

Redwood fibers

Redwood fiber insulations are not as widely used in industrial equipment and products as most other wood insulations. They are used principally to insulate large freezers, coolers and controlled atmosphere installations.

Redwood insulations are made largely from fibrous redwood bark, an extremely durable material. Thermal conductivity compares favorably with that of other insulations; k values range from a low of 0.17 at –120 F to a high of 0.28 at 90 F. Recommended density is about 4½ lb per cu ft.

The good thermal qualities of the insulation derive from its high content of minute air cells which, in addition to providing low conductivity, prevent convection current losses. The material is quite repellent to rodents and insects, and will not absorb odors. It is quite moisture resistant, but should always be used with a vapor barrier to prevent condensation.

Paper

The uses of paper for non-architectural insulations are rather specialized. The outstanding feature of paper is its low cost. It can be used in sheet form or impregnated with organic binders and molded into a variety of shapes. Structural strength, however, is quite low, and the material is not very resistant to moisture or fire. No information on thermal conductivity is available.

Cross-creped kraft paper (see "Cross-Creped Kraft," MATERIALS IN DESIGN ENGINEERING, Nov '57, p 138) can be used as high as 300 F and in some cases up to 400 F. Above 400 F scorching may occur and the material may suffer some embrittlement as moisture is driven off. No damage is suffered at low temperatures.

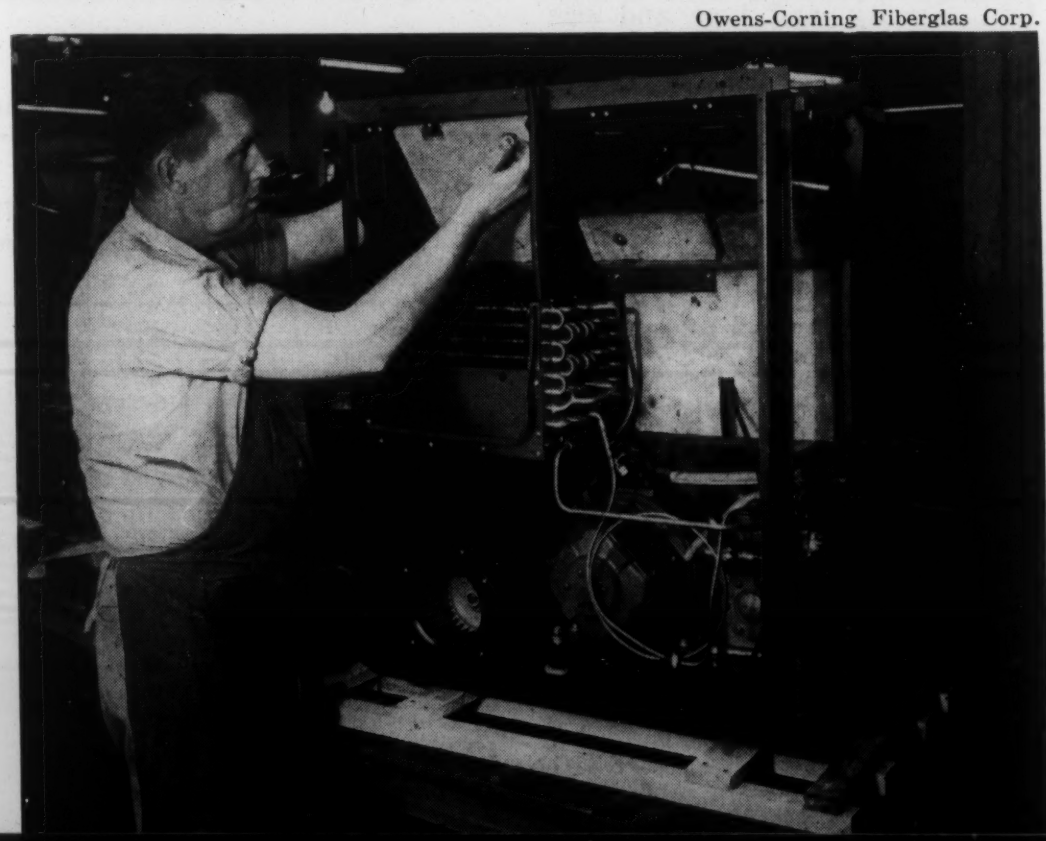
Westinghouse Electric Corp.

Rubatex Div., Great American Industries, Inc.

Refrigerator *parts (top) are insulated with prefoamed polystyrene, selected for its combination of thermal and structural properties. These properties are also characteristic of refrigerator truck insulation (bottom) which consists of cellular rubber.*

Central heating and cooling *unit is insulated with rigid glass fiber panels.*

Owens-Corning Fiberglas Corp.



Organic fibers and felts

Organic fiber insulations—both natural and synthetic—are used to some extent for light duty industrial applications.

With the exception of cotton and wool which are sometimes used in loose form, organic and synthetic insulating materials are usually used in felted form. Some of the principal felt insulating materials available are cotton, wool, rayon, Dynel, Arnel, Orlon, Dacron, acetate, Acrilan and nylon. Most of the materials are used alone; however, some of them may be combined with each other.

The fibrous, porous, matted structure of organic and synthetic felts makes for good thermal and acoustical insulation. In general, untreated natural wool felts can be used at temperatures as low as –110 F and continuously at temperatures as high as 250 F. They can also be used intermittently at higher temperatures. Temperature limits of synthetic felts are about the same, except that some of the materials can be used continuously up to 400 F. Thermal conductivity of both natural and synthetic felts (4 lb per cu ft density) is about 0.21 at room temperature.

In general, untreated wool or wool and cotton felts exhibit two types of combustion. Flaming combustion occurs when flammable gases produced by thermal decomposition unite with oxygen to produce flame. Flameless combustion occurs when oxygen combines with fibers to produce glowing. Flameproofing treatments can be applied to felts to make them self-extinguishing and to reduce the period of afterglow to seconds. Such treatments have no effect on the properties of the felt.

One of the most popular felt insulations contains cotton and rayon fibers bonded together with an inert phenolic resin. The phenolic binder provides the material with high resistance to mildew, mold and bacteria attack. Thermal conductivity of the insulation compares well with that of other insulations, ranging from 0.24 to 0.27 at a mean temperature of 75 F. Since its upper operating temperature limit is about 200 F, the material is primarily recommended for low temperature applications.

Plastics foams

Because of their cellular structure and large number of dead air spaces, plastics foams are ideally suited as thermal insulations. In addition to providing low thermal conductivity, these materials are also recommended because of their high strength-weight ratio, their low odor, their good resistance to water vapor, and their ease of fabrication.

In general, the thermal properties of plastics foams (see Table 8) are determined by resin content, density, and type and size of cellular structure. Some of the principal insulating foams in use today are: 1) rigid polystyrene which can be prefoamed or foamed in place; 2) flexible, semi-rigid or rigid urethanes which can be prefoamed or foamed in place; 3) rigid phenolics and silicones which are usually foamed in place; 4) soft and rigid polyvinyl chloride; and 5) rigid, prefoamed urea formaldehyde.

Rigid polystyrene

Two principal types of rigid polystyrene plastics foams are available for insulation purposes: prefoamed and foamed in place.

Prefoamed materials have excellent insulating properties (see "Plastics Foam Sandwich Used for Refrigerator Walls," MATERIALS & METHODS, May '57, p. 150), and its thermal conductivity compares favorably with that of other commonly used board insulation materials. Heat distortion temperature, and therefore maximum service temperature, is about 175 F. Properties of the material are not adversely affected by subzero temperatures.

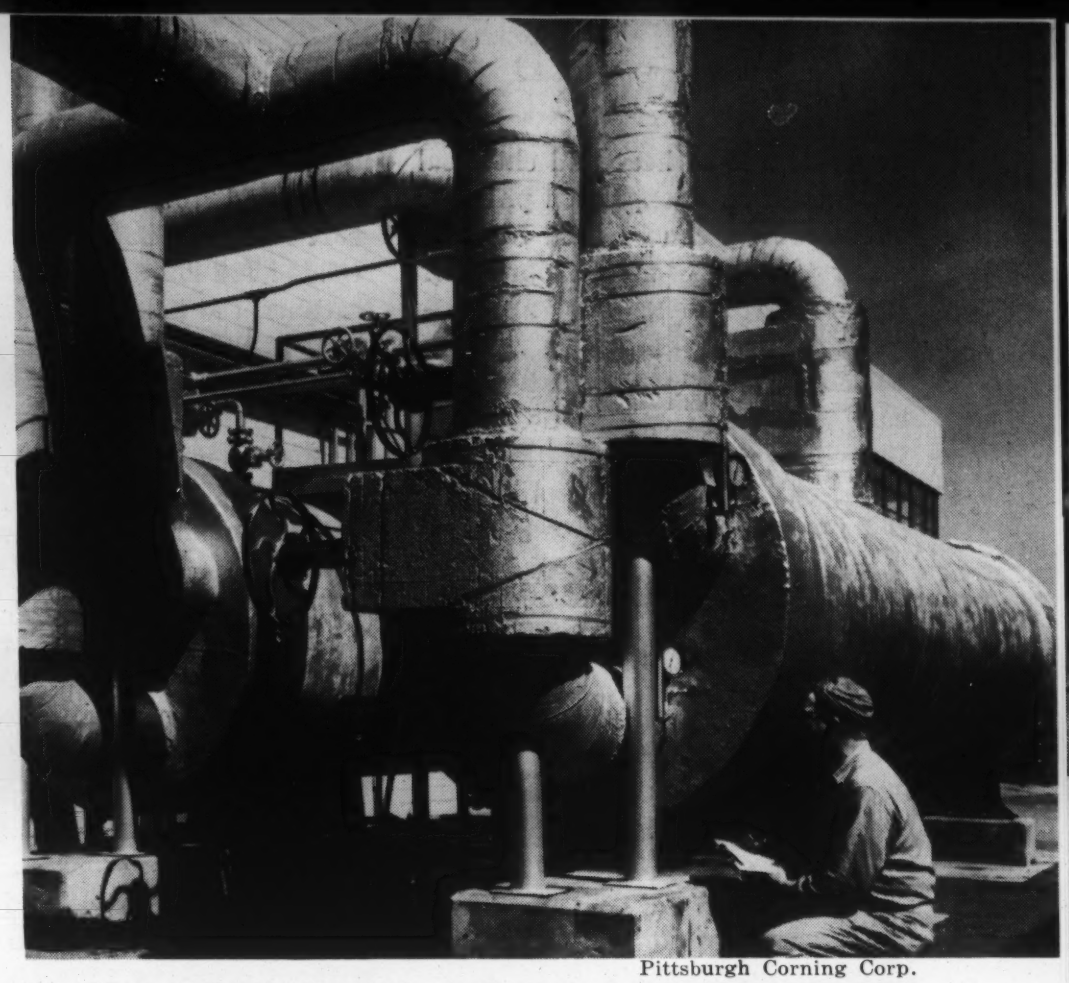
Because of its closed cell structure the material has excellent resistance to water. Water vapor transmission is very low, and the foam will not rot or support mold growth. The material is nontoxic, and its water and chemical resistance are similar to that of conventional polystyrene. It does not have particularly good acoustical insulation properties.

Earlier formulations had the

TABLE 8—COMPARATIVE THERMAL PROPERTIES OF PLASTICS FOAMS

Plastic ↓	Density, lb/cu ft	Ther Cond, Btu/hr/sq ft/°F/in.	Coef of Ther Exp, per °F	Max Cont Svc Temp, F
Polystyrene				
Prefoamed	1.7-2.3	0.226 (0 F), 0.295 (100 F)	$3\text{-}4 \times 10^{-5}$ (0 to 80 F)	175
Foamed-In-Place	2.5	0.205 (0 F), 0.257 (100 F)	—	170
Urethane				
Semirigid	2.0	0.20	1.4×10^{-5} (–22 to 86 F)	200
Rigid	2.0	0.23	1.9×10^{-5} (32 to 140 F)	200-400
Silicone	12-16	0.3	—	700
Phenolic	1.7	0.24	—	300
Polyvinyl Chloride (rigid)	4-7	0.23	—	110
Urea Formaldehyde	0.8	0.20 (100 F)	—	120

Johns-Manville Corp.



Pittsburgh Corning Corp.

***Tanks** and other large containers can be protected with a variety of insulations. Typical of these are an asphalt-asbestos coating (left) and cellular glass blocks (right).*

disadvantage of being flammable. However, a formulation has been developed which is self-extinguishing and which melts, does not burn, on contact with flame.

Foamed - in - place insulations have densities of 1.5 to 15 lb per cu ft. They can be used at temperatures up to about 170 F, and self-extinguishing grades are available. In addition to low thermal conductivity, they also possess low water absorption and water vapor permeability, and are odorless and resistant to fungi. All molded foam pieces have a dense, hard smooth skin which enhances strength properties.

In addition to the two polystyrene systems described above, a promising new plastics foam is currently being developed. The system (see MATERIALS & METHODS, Apr '57, p 142) combines expandable polystyrene beads and an exothermic-type thermosetting resin, usually an epoxy.

Density of the foam ranges from 5 to 20 lb per cu ft. As in other polystyrene foams, thermal conductivity is low—on the order of 0.24. Water resistance is also low because of the hard epoxy surface and unicellular structure.

This unicellular structure, combined with good structural strength and low thermal conductivity, makes the foam a promising material for refrigeration uses such as doors, cabinets, freezer lids and evaporator doors. A refrigerator door has been produced by expanding the foam between molded high impact polystyrene sheets. Also, doors have been made with molded-in lock mechanisms, latches, hinges, gaskets and fixtures. The epoxy resin that is driven to the surface provides the adhesion to bond the inserts firmly in place. Other potential low temperature applications include transportation and air conditioning equipment.

Urethanes

Urethane foams are not as widely used for insulation purposes as the polystyrene foams. Nevertheless, they do provide low thermal conductivity as well as excellent mechanical strength, cushioning properties, and resistance to abrasion and chemicals.

The thermal conductivity of semi-rigid systems increases linearly with increasing density. K values range from a low of 0.20 at a density of 1 lb per cu ft to 0.30 at 20 lb per cu ft. A similar trend is shown by rigid urethane foams; k values range from about 0.23 at 1 lb per cu ft to 0.43 at 20 lb per cu ft.

Silicones

The principal advantage of rigid silicone insulating foams is their heat resistance. Some can withstand continuous exposure to temperatures above 700 F. The foams are also extremely resistant to thermal shock and, when exposed to direct flames, become red hot, do not burn, and show only slight surface change. Average thermal conductivity of the foams is about 0.3 at densities from 12 to 16 lb per cu ft.

Silicone foams can be obtained both as foam-in-place formulations and as block and sheets. Principal applications include thermal and electrical insulation in missiles and high speed aircraft, as well as in specialized electronic equipment.

Phenolics

Rigid phenolic foams have excellent thermal and acoustical properties. Optimum thermal insulation properties are obtained with densities of about 1 lb per cu ft. Thermal conductivity at this density is roughly 0.23.

Phenolic foams have about the

same degree of heat and chemical resistance as unexpanded phenolic resins. They can be used for continuous service at temperatures up to about 300 F. They are self-extinguishing, and they can be used in contact with most chemicals (with the exception of certain alkalis), alcohols and ketones. Principal insulation applications to date have been honeycomb components in sandwich constructions.

Polyvinyl chloride

Closed cell polyvinyl chloride foams are available in soft to rigid sheets and in molded forms for thermal insulations. Outstanding characteristics of these foams are: 1) low thermal conductivity, 2) light weight (5 to 30 lb per cu ft), 3) impermeability, 4) fire resistance (optional), and 5) chemical inertness.

K values range from 0.23 for the rigid form to 0.25 for the soft form. Although primarily intended for low temperature applications, the materials can be used at continuous operating temperatures up to 110 F, and intermittently as high as 200 F.

The good insulation properties and water resistance of polyvinyl chloride foams are demonstrated by their use in ice buckets. Large cakes of ice placed in covered rigid containers have remained more than 40% unmelted after seven days exposure at room temperature.

Although the foam becomes firm at low temperatures, it still remains flexible. At 0 F, it loses most of its resilience and is firm, but even at –40 F it can be bent without cracking.

Urea formaldehyde

Rigid, expanded urea formaldehyde plastic, with an interwoven crystalline structure containing about 99% air by volume, is one of the lightest organic foams available. Its density is about 0.8 lb per cu ft, and the material is produced in the form of large blocks (about 20 x 10 x 4 in.) or as shredded insulations. Primary uses of these materials are low temperature insulation and acoustical insulation.

Shredded insulation has a k factor of 0.18 at 75 F and 0.20 at 100 F. The material can be used continuously at temperatures up to 120 F. Exposure to direct flame causes volatilization, but the material will not support combustion and is self-extinguishing. It is not affected by low temperatures.

Cellular rubber

Both natural and synthetic cellular rubbers are available for thermal insulations. In addition to their low thermal conductivity these materials are also noted for their: 1) light weight, 2) availability in soft or hard forms in a variety of shapes, 3) high resistance to moisture and vermin, 4) easily cleaned and sanitary surfaces.

The low thermal conductivity of cellular rubber derives from its high content of tiny closed cells filled with nitrogen. With the exception of the nitrogen content, the structure of these materials is quite similar to that of foam plastics.

TABLE 9—TYPICAL PROPERTIES OF CELLULAR RUBBER INSULATION

Type ➡	Soft	Hard
Ther Cond, Btu/hr/sq ft/°F/in.	0.27-0.30	0.20-0.25
Density, lb/cu ft..	8-18	5-20
Water Absorp, %[a]	5	5
Compr Set, %[b]..	40-50	—
Compr Str, psi...	—	30-400[c]
Flex Str, psi.....	—	250-650 (8-10 lb/cu ft); 1000-1500 (20 lb/cu ft)

[a]ASTM D1056-49T. [b]ASTM D552-46aT. [c]Depends on density.

As shown in Table 9, cellular rubber is available in both soft and hard forms. Thermal conductivity and density of both forms are quite similar.

Soft rubber

Density of the soft rubber ranges from 8 to 18 lb per cu ft, and the material is produced as flexible tube, cord and strip. The soft material was developed primarily to overcome the loss in efficiency which can occur with open cell (sponge) rubber tubing when used as an insulation on cold water lines. Open cell rubber has a marked tendency to absorb the condensation formed on lines during hot humid conditions. Because of its closed structure, cellular rubber is impervious to water vapor and will not lose its efficiency.

The soft material has a tendency to harden gradually at low temperatures. It remains flexible at temperatures down to –20 F, becomes quite firm at –40 F, and becomes brittle at –50 F. However, the physical properties of the insulation are restored when it is brought back to room temperature.

Soft cellular rubber can also be used to insulate pipes carrying hot liquids. Except for an increase in hardness, its insulation and other properties remain unchanged as temperature is increased. After three months at 158 F the material experiences an increase of about 30 to 40% in firmness and 12 to 15 points in durometer hardness. After five months at 200 F, firmness approximately doubles and durometer hardness increases 40 to 50 points. Maximum recommended operating temperature of the material is about 250 F. Exposure for one week at this temperature produces a hard brittle material with a durometer increase of 60 points.

Hard rubber

Compared to other insulation materials, hard cellular rubber has a very favorable strength-weight ratio. It is rigid, firm and quite light. It is available in densities of 5 to 20 lb per cu ft, and

can be molded or made in sheets up to 20 x 36 x 1½ in. Because of its thermoplastic properties, the material can be post-formed by heating and shaping; original properties of the insulation are retained after cooling. The material is also easily machined, filed or sawed.

Hard cellular rubber can be compounded with many special properties. It can be made resistant to strong acids and to oils, and suitable for continuous operation at 290 F. It will not disintegrate, crumble or become waterlogged, and will last indefinitely if not unduly damaged.

Hard cellular rubber in block or sheet form is used principally in the construction of cold boxes and refrigerator rooms and trucks. Because of its high structural strength, it can be used for walls and ceilings without reinforcement. Also, because of its cellular structure, it does not lose its insulation value through internal condensation and ice formation.

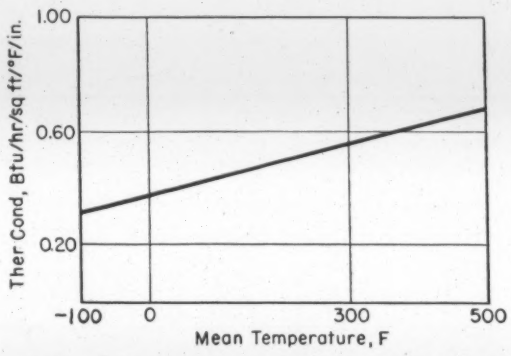
Cellular glass

Cellular glass can be used for both low and high temperature insulations. It has good thermal efficiency, it is noncombustible, and each cell provides an effective barrier against convection currents and moisture diffusion.

The material is made by heating pulverized glass with a gasifying substance to a temperature that causes the glass to flow. As the gas expands it forms hollow cells or voids which amount to about 90% of the total volume of the material. After the glass has completely expanded into a closed container it is removed in the form of rigid blocks and then cut to the desired shape.

Properties

As shown in Fig 3, the thermal conductivity of cellular glass varies linearly from 0.22 to 0.68 over a temperature range of –100 to 500 F. The material is particularly suitable for uses below 32 F because it is impervious to water vapor and because no condensation can take place within the cells. The combination of cellular structure and inorganic constituents also enables the material to retain its rigidity and mechanical properties at temperatures up to 800 F.



***Cellular glass** thermal conductivity from —100 to +500 F.*

Cellular glass has roughly the same density as the heavier foam plastics—about 10 lb per cu ft. Other significant properties are listed in Table 10.

Applications

Some of the principal uses of cellular glass are cold insulations at –50 to +50 F. Such insulations include walls, ceilings and floors of cold storage rooms, as well as refrigeration equipment and piping. Although cellular glass is inherently protected against internal moisture condensation, it is necessary to seal all joints with a suitable mastic material to prevent water vapor from penetrating through the seams and condensing on chilled inner surfaces. Also, when used in applications where it is liable to be loaded, cellular glass must be protected by a layer of material such as cement that will distribute concentrated loads over a large area.

Cellular glass can be placed in contact with parts operating at temperatures as high as 800 F. It is installed just like other inorganic block insulations. Where large areas are involved, allowance should be made for differences in expansion between the insulation and the base material.

TABLE 10—PROPERTIES OF CELLULAR GLASS

Ther Cond, Btu/hr/sq ft/°F/in.	
0 F	0.35
50 F	0.38
70 F	0.39
Specific Heat, Btu/lb/°F	0.20
Coef of Ther Exp, per/°F	0.46 x 10^{-5}
Density, lb/cu ft	8-10
Moisture Absorption, % by vol	0.2
Modulus of Elasticity, psi	180,000
Strength, psi	
Compressive	100
Flexural	75
Shear	64
Tensile	84

***Ice bucket** made from closed cell polyvinyl chloride has high thermal efficiency and structural strength.*
B. F. Goodrich Co.

Reflective surfaces

The value of reflective insulations in architectural and in some product applications is well known. It has been shown that air spaces give much better insulation if they contain highly reflective surfaces. Similarly, the insulating efficiency of most insulating materials of blanket, batt or board form is increased by the use of reflective aluminum foil or paint. In many such applications, the aluminum foil also serves as a vapor barrier.

Reflective insulations are not very effective in hindering the flow of heat by conduction or con-

L.O.F. Glass Fibers Co.

***Jet engine parts** are sometimes insulated from excessive heat, as well as air stream erosion and accidental damage, by high temperature glass fiber insulation protected by flexible Inconel jacket.*

vection. They are primarily designed to reflect (not to absorb) radiant energy. The ability of a surface to emit and absorb radiant energy is measured by its emissivity or "e" value. The lower the emissivity value, the lesser the ability of the surface to emit or absorb radiant energy. Thus, a material with a low emissivity value has high reflective properties. An ideal black body has an emissivity of 1.0 (i.e., zero reflectivity) and an ordinary dark rough surface an emissivity of 0.90. Compared to these surfaces, bright metal has an emissivity of 0.05, and semi-reflective surfaces have emissivities ranging from 0.15 to 0.50.

The maximum operating temperature of reflective aluminum foil is a function of the material's melting point. Aluminum begins to melt at about 1070 F; for this reason the material is not generally recommended for operation above 700 F.

Asphalt coatings

As mentioned previously, asphalt impregnants are sometimes used on fiber insulations to promote bonding and to improve resistance to moisture and chemicals. In addition to this function, asphalt is frequently used in coating form as an insulation over bare metal surfaces or as a protective insulation over a primary insulation.

Asphalt-cork types

Asphalt coatings are supplied in several compositions, each having a specialized function. One of the principal compositions available consists of an asphalt-base mastic containing a high volume content of screened ground cork and a small amount of long asbestos fibers. The asphalt forms a matrix that firmly bonds and seals the individual cork particles which are uniformly distributed and serve to lower thermal conductivity. Available in medium and heavy grades, both of which can be applied by spraying (the heavy grade can also be applied with a trowel), this composition cures to a tough and abrasion resistant coating with good insulating properties and resistance to weather and water vapor transmission.

The coating alone has a thermal conductivity of 0.5 to 0.7. A ¼-in. film of the material commonly reduces the heat loss of oil storage tanks up to 65%. The allowable operating temperature range of cured films ranges from –40 to +275 F. The coating becomes heat resistant after curing, and does not support combustion unless the heat becomes so intense as to decompose the asphalt.

Coatings are usually applied in thicknesses of ¼ to ⅜ in. and cure to a black surface having a pleasing pebbled appearance. In addition to providing low thermal conductivity, asphalt coatings act as a weather and vapor barrier to protect underlying surfaces from condensation, corrosive and weathering elements, and also as a sound deadener. The coatings are not intended to replace conventional insulations which are normally applied in thicknesses of more than 1 in. to obtain heat loss reductions of 80% or more.

The asphalt-cork coatings are largely used to insulate and protect chemical and petroleum processing equipment and similar equipment. Typical applications are: fractionation towers, oil or water storage tanks, walls, ceilings and panels in buildings, and pipes and ducts. The coatings are also used on truck, bus and railway cars where a combination of insulation, vapor and weather protection, and sound deadening properties are needed.

Other types

In addition to the above types, a number of other asphalt compositions are widely used. An asphalt-base plastic composition serves as a non-breathing vapor and water barrier over insulation and metals. Another type containing fibrous and expanded low density mineral fibers is recommended as a breathing, waterproof barrier over high temperature insulations. Still another composition containing catalytic asphalt and mineral fillers is recommended as a bedding and joint compound for low temperature insulation with a service range of –100 to +200 F. Asphalt cements, primers and coating vehicles are also available.

Acknowledgments

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Aluminum Co. of America
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Chicago Stock Yards Research Div.
Corning Glass Works
Dow Chemical Co.
Eagle-Picher Co.
E. I. du Pont de Nemours & Co., Inc.
Ehret Magnesia Mfg. Co.
Felt Assn.
Forest Products Laboratory
Gustin-Bacon Mfg. Co.
Johns-Manville Corp.
Keasbey & Mattison Co.
Koppers Co.
Libby-Owens-Ford Glass Fibers Co.
Lion Oil Co., Div. of Monsanto Chemical Co.
Magnesia-Silica Insulation Mfgrs. Assn.
Minnesota Mining & Mfg. Co.
Mobay Chemical Co.
Nopco Chemical Co.
Owens-Corning Fiberglas Corp.
Philip Carey Mfg. Co.
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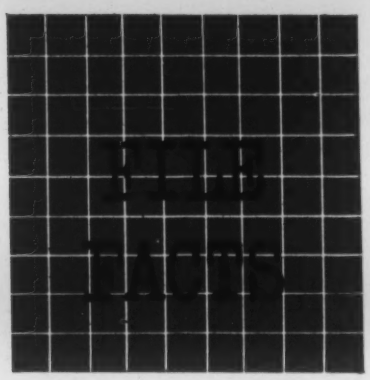
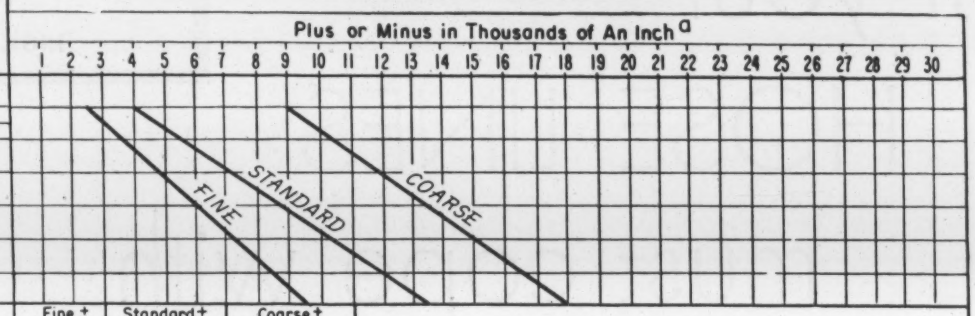
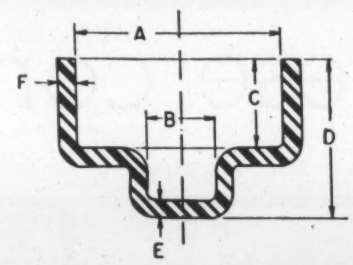
Recommended Design Tolerances for Plastics Moldings—Part 1



Unfilled Phenolics



Drawing Code	Dimensions (in.)	Fine ±	Standard ±	Coarse ±
A = Diameter or Length B = Diameter or Length C = Depth	6.000 to 12.000 For each inch over 6.000 add (in.)	0.0015	0.002	0.0025
	Over 12.000 For each inch over 12.000 add (in.)	0.002	0.0035	0.0055
HEIGHT D	Single Cavity 0.000-1.000	0.008	0.010	0.012
	Multiple Cavity 0.000-1.000	0.010	0.012	0.014
	For each inch over 1.000 add (in.)	0.002	0.0035	0.005
BOTTOM WALL E	0.000 to 0.100	0.0045	0.0065	0.0085
	0.100 to 0.200	0.0045	0.0065	0.0085
	0.200 to 0.300	0.0045	0.0065	0.0085
SIDEWALL F DIMENSION b		Section thickness to be held relatively constant		
F Variation in wall thickness due to eccentricity, 0.005-0.007 in. Interlocking reduces this.				
DRAFT ALLOWANCE		1/8°	1/4°	1°

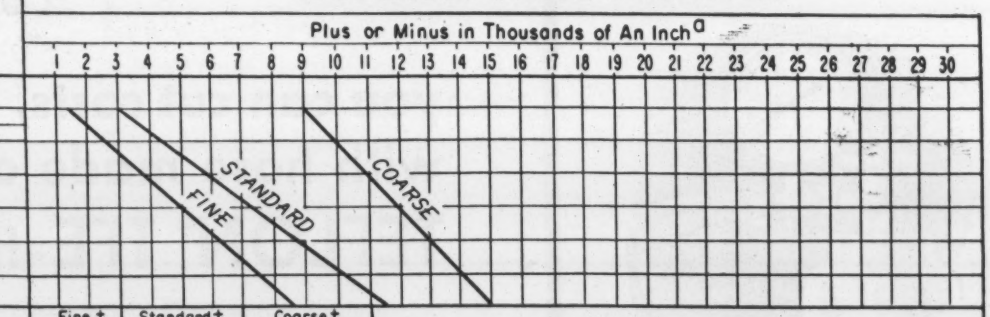


a These tolerances do not apply to screw threads, gear teeth or fit of mating parts; dimensions in these classifications can generally be held to closer limits. These tolerances do not include allowance for aging characteristics of material.

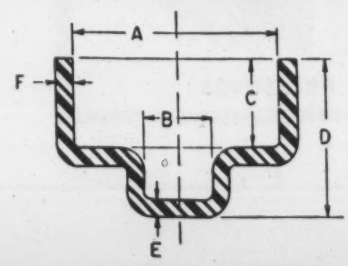
b For further information see discussion in Plastics Engineering Handbook.

DWG. CODE			
D, E	Compression Molded. For projected area over 20 sq in.	Fine	Add 0.001 in. for each additional 10 sq in.
		Standard	Add 0.002 in. for each additional 10 sq in.
		Coarse	Add 0.003 in. for each additional 10 sq in.
	Transfer, jet, or injection molded. Any area		PLUS OR MINUS TOLERANCE IN THOUSANDTHS OF AN INCH (F = Fine; S = Standard; C = Coarse)
			1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
D	Single cavity		F S C
D	Multiple cavity		F S C
D	For each inch of depth over 1.000 add (in.)		0.001

Woodflour-Filled Phenolics



Drawing Code	Dimensions (in.)	Fine ±	Standard ±	Coarse ±
A = Diameter or Length B = Diameter or Length C = Depth	6.000 to 12.000 For each inch over 6.000 add (in.)	0.0015	0 002	0.0025
	Over 12.000 For each inch over 12.000 add (in.)	0 002	0.003	0.005
HEIGHT D	Single Cavity 0.000-1.000	0.004	0.006	0.008
	Multiple Cavity 0.000-1.000	0.006	0.008	0.010
	For each inch over 1.000 add (in.)	0.002	0.005	0.008
BOTTOM WALL E	0.000 to 0.100	0.003	0.005	0.008
	0.100 to 0.200	0.003	0.005	0.008
	0.200 to 0.300	0.003	0.005	0.008
SIDEWALL F DIMENSION b		Section thickness to be held relatively constant		
F Variation in wall thickness due to eccentricity, 0.005-0.007 in. Interlocking reduces this.				
DRAFT ALLOWANCE		1/8°	1/4°	1°



a These tolerances do not apply to screw threads, gear teeth or fit of mating parts; dimensions in these classifications can generally be held to closer limits. These tolerances do not include allowance for aging characteristics of material.

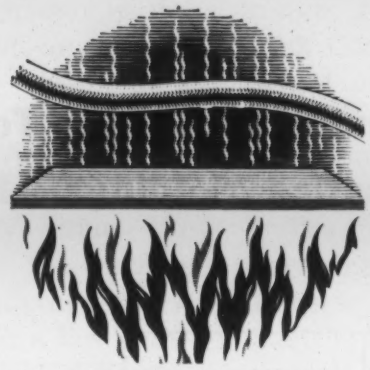
b For further information see discussion in Plastics Engineering Handbook.

DWG. CODE			
D, E	Compression Molded. For projected area over 20 sq in.	Fine	Add 0.001 in. for each additional 10 sq in.
		Standard	Add 0.002 in. for each additional 10 sq in.
		Coarse	Add 0.003 in. for each additional 10 sq in.
	Transfer, jet, or Injection Molded. Any area		PLUS OR MINUS TOLERANCE IN THOUSANDTHS OF AN INCH (F = Fine; S = Standard; C = Coarse)
			1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
D	Single cavity		F S C
D	Multiple cavity		F S C
D	For each inch of depth over 1.000 add (in.)		0.001

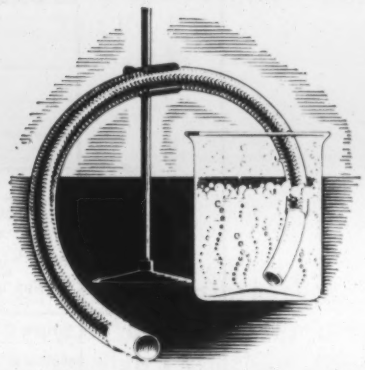
Source: *Plastics Engineering Handbook* of the Society of the Plastics Industry, Inc., Reinhold Publishing Corp., 1954.

For more information, circle No. 496

If your HOSE LINES must cope with these conditions...

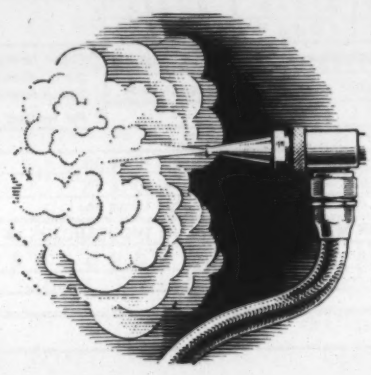


HIGH TEMPERATURES

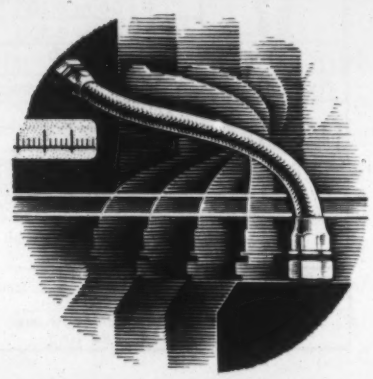


CORROSIVE CHEMICALS

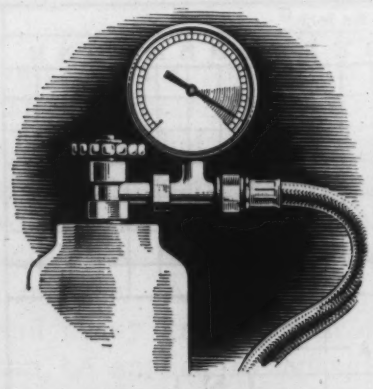
ADHESIVES



LIVE STEAM



FLEXING AND IMPULSING



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In Canada: Du Pont Company of Canada (1956) Limited, P.O. Box 660, Montreal

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What's new IN MATERIALS

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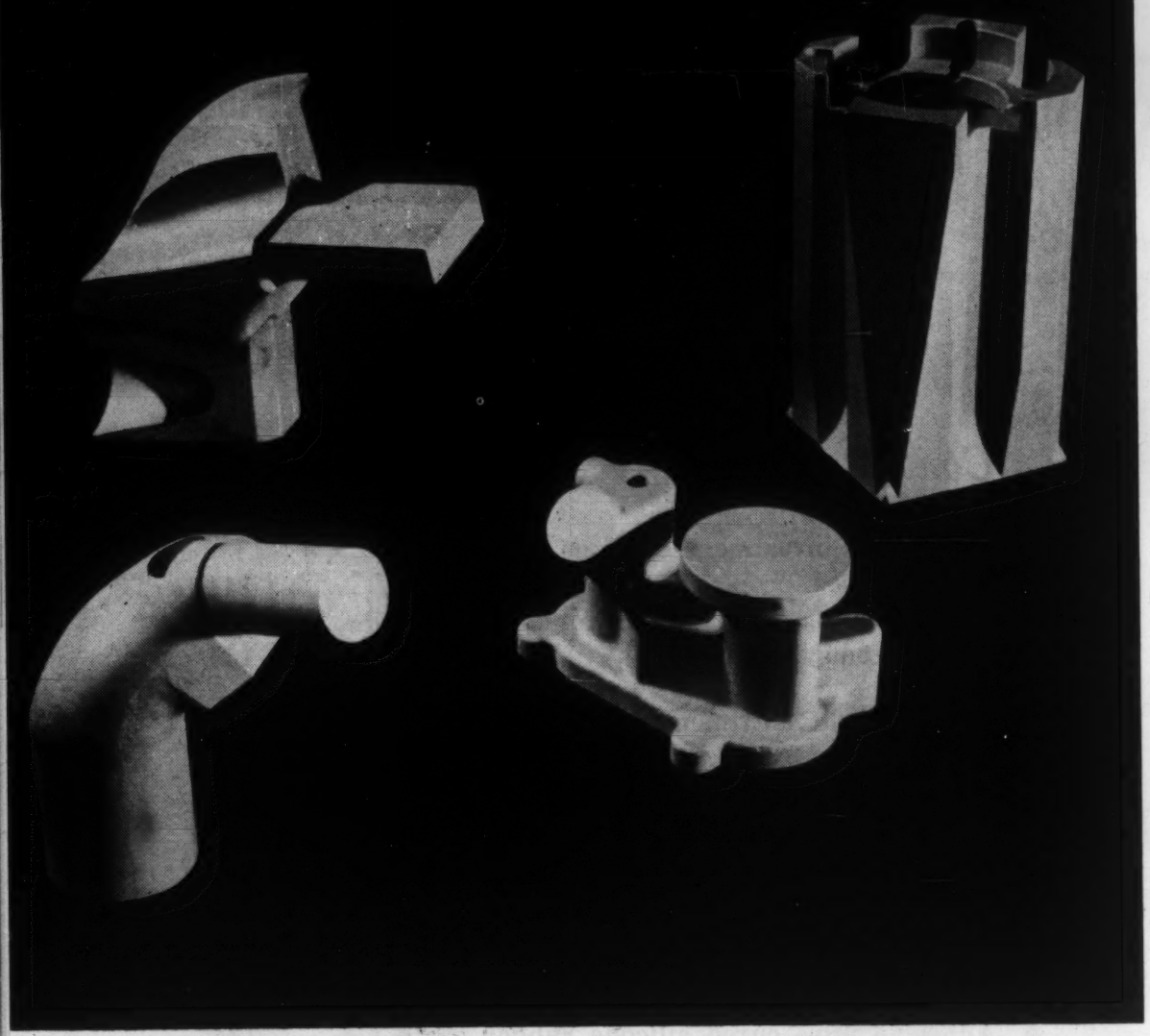
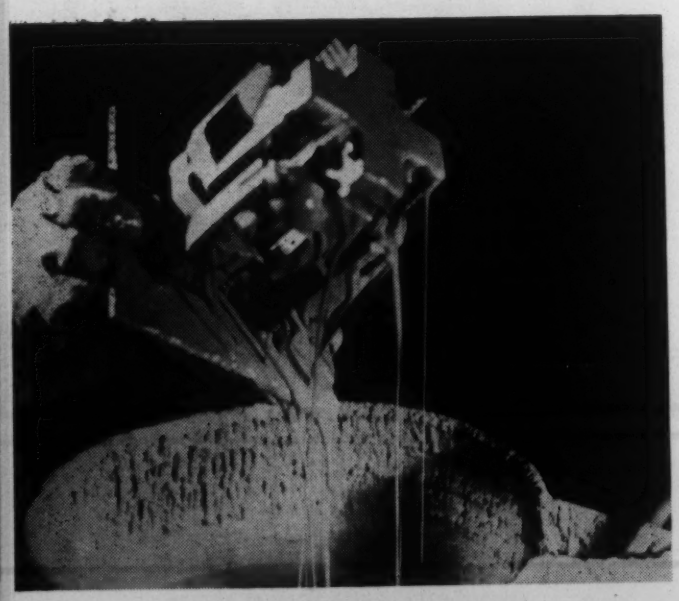


Complex aluminum parts *like these can now be investment cast—with guaranteed mechanical properties.*

Aluminum Investment Castings with Guaranteed Properties



***Wax pattern** is dipped in ceramic slurry in preliminary stages of investment casting process.*

■ A new investment casting technique is said to result in aluminum castings with 54% higher tensile strength, 64% higher yield strength and 600% higher elongation than are required by Aeronautical Material Specifications. Moreover, these improved properties are guaranteed. As a result, wider structural use of aluminum investment castings is predicted in aircraft applications.

According to Arwood Precision Casting Corp., this is believed to be the first time aluminum investment castings have been offered with guaranteed properties. The accompanying table compares AMS with Arwood's guarantees. As shown, there are significant improvements. In addition, Arwood claims that as a result of the new casting technique (thus far the company declines to publish details), certain critical areas in castings can be provided with even higher guaranteed properties.

Another significant aspect of this development is that many parts can now be cast which previously could only be formed by forging or machining. According to William Sweeny, Arwood's president, "Aluminum investment castings were previously limited mainly to fittings or 'hardware' applications. Added properties of strength and ductility, however, permit designers to use them as structural, load carrying parts, subject to shock and impact. And they can do it without any change in specs."

PROPERTIES OF ALUMINUM INVESTMENT CASTINGS

Property ↓	AMS[a]	Guaranteed Minimum	Critical Area Guarantee
Tensile Strength, 1000 psi	24.8	34	38
Yield Strength, 1000 psi	16.5	25	27
Elongation, %	0.7	3	5

[a]Aeronautical Material Specification.

Epoxy Tooling Now Possible for Medium Run Production Dies

A new family of heat resistant epoxy resins reinforced with metal and glass fibers has been developed by Bakelite Co. (a division of Union Carbide Corp.), 30 East 42nd St., New York 17, for plastics tooling. Called Epoxy Alloys, the compositions are said to extend the use of plastics tooling compounds from prototype and low production metal forming dies, used at present, to medium run metal forming dies. For instance, one such die has turned out more than 130,000 stampings of a 0.025-in. thick brass automotive radiator cover; another has formed more than 65,000 units for a refrigerator section.

Bakelite Co. engineers say, "Epoxy Alloy refers not only to a new metal fiber-reinforced plastics material, but also to a method for effectively using this material. In brief, an Epoxy Alloy tool or die is a mass casting made by a pressure process; the cast dies are then surfaced with an epoxy face coat reinforced with chopped metal fibers."

Three types

To date, three types of Epoxy Alloy compositions have been developed:

ES — Epoxy resin reinforced with steel fibers; castings made from this composition are surfaced with an epoxy steel-fiber-flocked face coat.

EG-SF—Epoxy resin reinforced with glass fibers; castings made from this composition are surfaced with an epoxy steel-fiber-flocked face coat.

EA — Epoxy resin reinforced with aluminum fibers; castings made from this composition are surfaced with an epoxy aluminum-fiber-flocked face coat. This composition is designed for tooling applications other than metal forming dies that require high thermal conductivity such as low pressure, heated matched molds and green sand foundry patterns.

Details on the properties, uses and fabrication of the new plastics tooling compounds were given by A. P. Mazzucchelli, of Bakelite's Development Laboratories, before the 13th Annual Conference of the Reinforced Plastics Div., Society of the Plastics Industry, Inc., held during February in Chicago.

Properties

One of the most important characteristics of the new compounds in tooling applications, Mr. Mazzucchelli said, is their ability to be cast without sacrifice of toughness or other physical properties. A heat resistant epoxy resin system was chosen as the basis for these compositions because such a system, when reinforced with metal or glass fibers, was found to reduce greatly the problems of wear, galling, erosion and creep often encountered in plastics dies cast from room-temperature-curing epoxies. A heat resistant epoxy also provides a tool and die material with improved high temperature resistance and longer pot life than a room-temperature-curing epoxy.

65,000 *refrigerator parts have been produced on this Epoxy Alloy die using 0.035-in. steel sheets.*

According to Mazzucchelli, the use of metal fibers as a reinforcing material reduces the problems of shrinkage and brittleness experienced with most heat resistant epoxies. Metal fiber reinforcement also extends the maximum continuous operating temperatures of heat resistant epoxies to at least 350 F. (For information on metal fibers, see MATERIALS & METHODS, Nov '55, p 96.)

Metal fibers flocked on the surface of an epoxy casting are said to impart good abrasion resistance to the surface of a metal forming die, eliminate resin drainage, and provide a uniform coating with high strength.

Other characteristics of Epoxy Alloy dies, as outlined by Mazzucchelli:

1. They have high heat resistance and good thermal shock resistance.

2. Dies of the ES type (steel fiber reinforcement) can be made

PROPERTIES OF EPOXY ALLOYS

Type →	ES	EG-SF	EA
PHYSICAL PROPERTIES			
Thermal Conductivity, Btu/hr/sq ft/°F/in.	24.5	5	91.0
Water Absorption (24 hr immersion), %	0.30	0.40	0.35
Specific Gravity	2.25	1.55	1.80
Coef of Ther Exp, per °F	43 x 10^{-6}	—	55 x 10^{-6}
Max Operating Temp, F	350	350	350
MECHANICAL PROPERTIES			
Izod Impact Strength, ft-lb/in.	1.2	11	1.1
Flexural Strength, psi	13,500	22,500	11,000
Flexural Modulus, 10^{-6} psi	0.6	1.5	0.7
Compressive Strength, psi	20,500	25,000	16,500
Rockwell Hardness	M 82	M 107	M 69
Heat Distortion Temp, F	>400	>400	>400

These universal testing machines

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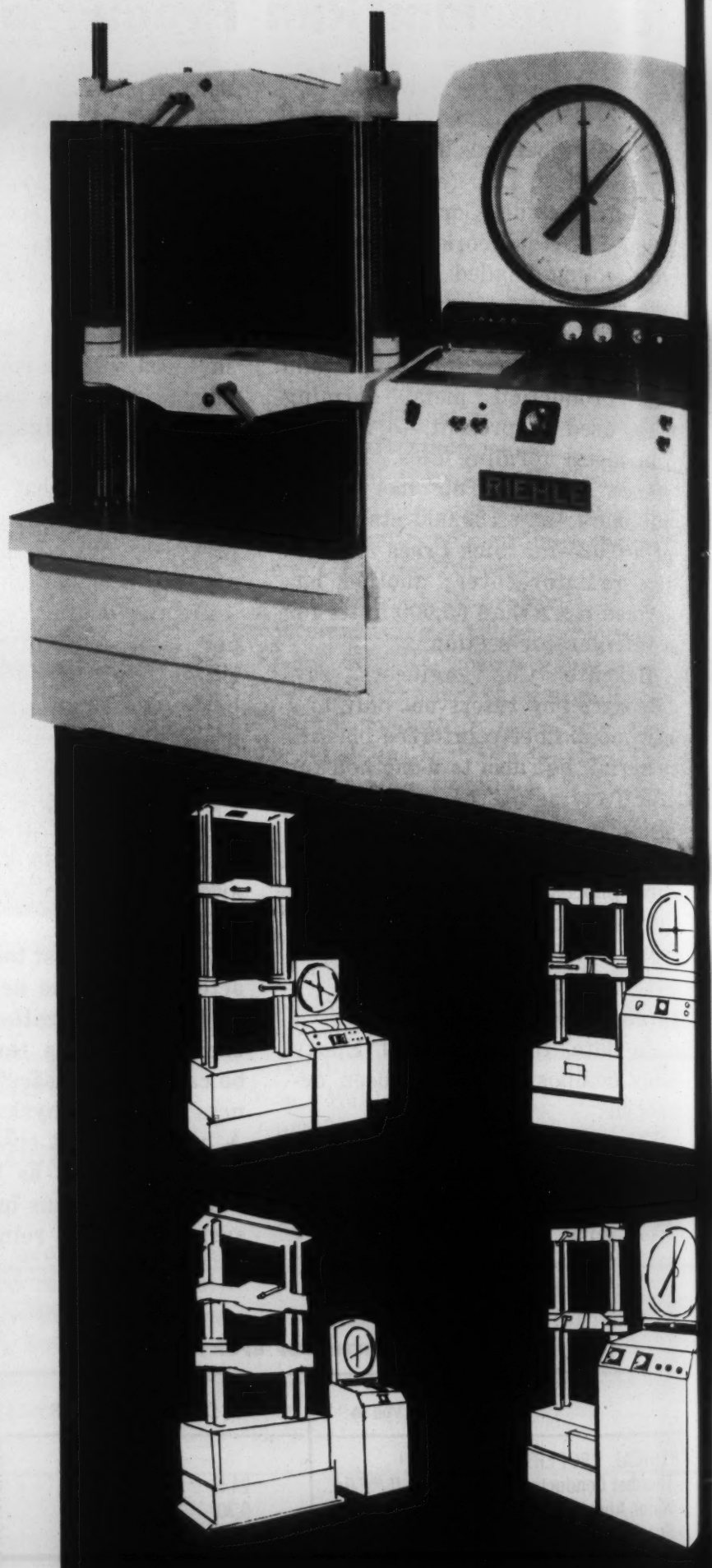
Hydraulic and screw power testing machines are available in capacities from 2,000 lbs. to 450,000 lbs. as standard. Riehle welcomes special application problems for testing equipment.



OTHER RIEHLE TESTING MACHINES: Creep and Stress-Rupture Testing Machines, Hydraulic Fatigue Testing Machines, Construction Materials, Impact, Brinell, Torsion, Horizontal Chain, Rope and Cable Testers, Portable Hardness Testers for Rockwell Readings, Etc.

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magnetic for easy handling.

3. They can be repaired easily by plug techniques.

4. They can be machined easily.

Uses

Based on actual production runs, Epoxy Alloy compounds should find use for the following tooling applications: prototype or development draw dies; low production draw dies; flanging, trimming, restrike and secondary operation dies; medium production draw dies; Hydroform and rubber pad forming dies; medium-high production draw dies; stretch dies; and fixtures and gages.

Fabrication

A casting pressure of 200 to 300 psi is recommended for steel fiber-reinforced compositions (ES) and 50 to 100 psi for glass fiber-reinforced compositions (EG-SF). Fiber content is about 55 to 60% by weight for steel, 45 to 50% for aluminum, and 50% for glass.

Better mechanical properties from . . .

Solution Heat Treatment of Magnesium Forgings

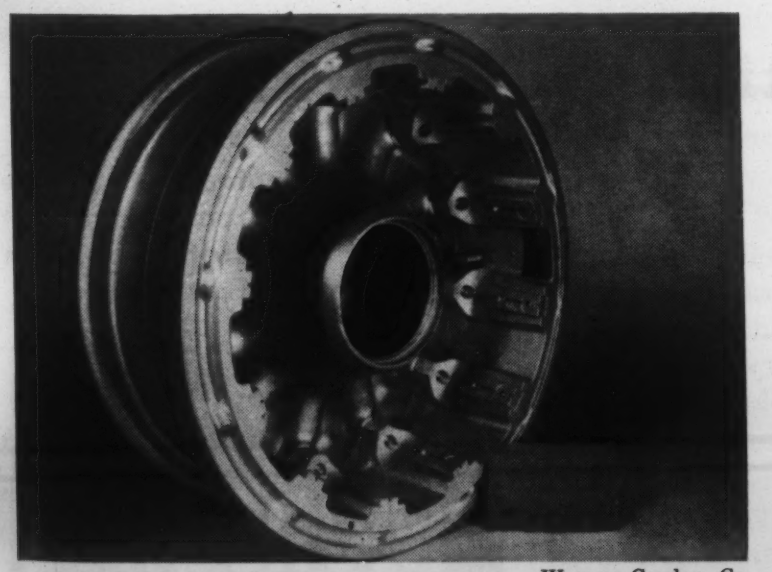
■ According to Dow Chemical Co., it is now possible to solution heat treat, quench and age ZK60A forgings to the –T6 condition, thereby improving yield strength, tensile strength and creep resistance.

Because of their extreme light weight, magnesium forgings have long been considered for use in airborne equipment and structures, especially where design requirements call for good stiffness-weight ratio and/or fatigue strength. However, up until very recently, the usefulness of magnesium forgings had been severely limited: because mechanical properties depend upon the amount of working during the forging operation, complex forgings with varied section thicknesses, and large forgings in which cast stock is used, required considerably more work than was practicable. These restrictions are said to have been eliminated by Dow's new procedure.

Properties

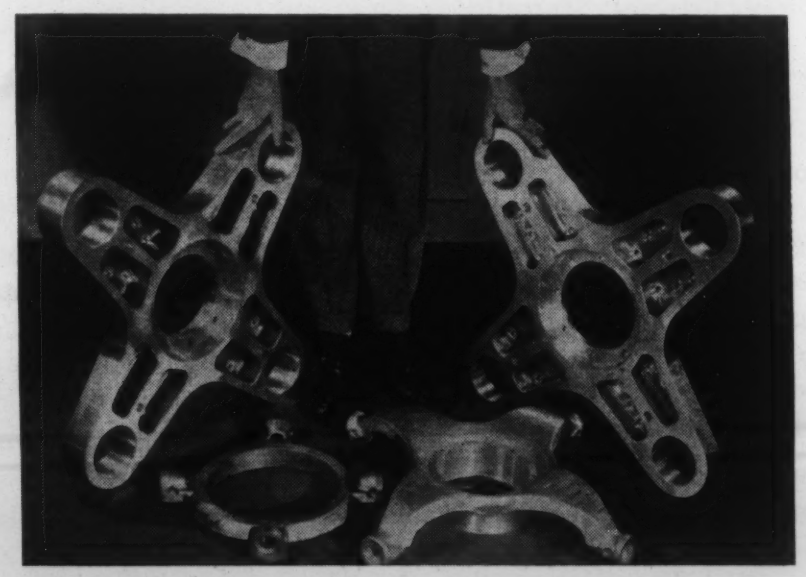
The accompanying table compares mechanical properties of ZK60A alloy in the conventional –T5 temper, the –F temper and the new T6 temper. As shown, the most significant increase is in yield strength and in the ratio of yield to ultimate strength. Short time elevated temperature strength and creep strength have also been improved: ZK60A-T6 forgings are said to have the same properties at 400 F as the conventional

Two magnesium forgings



Wyman-Gordon Co.

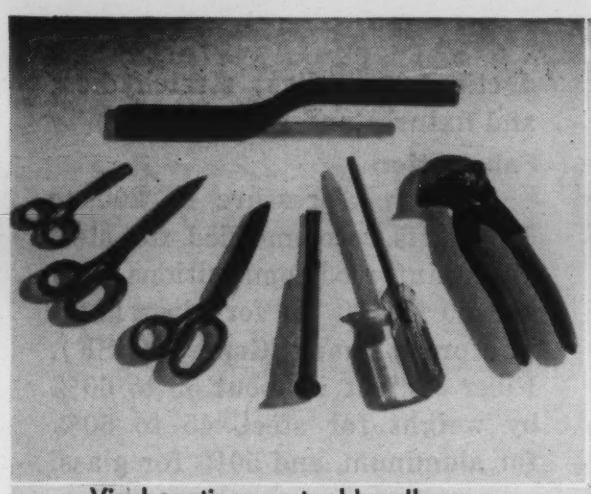
Main wheel *for Grumman F11F fighter weighs only 27.4 lb.*



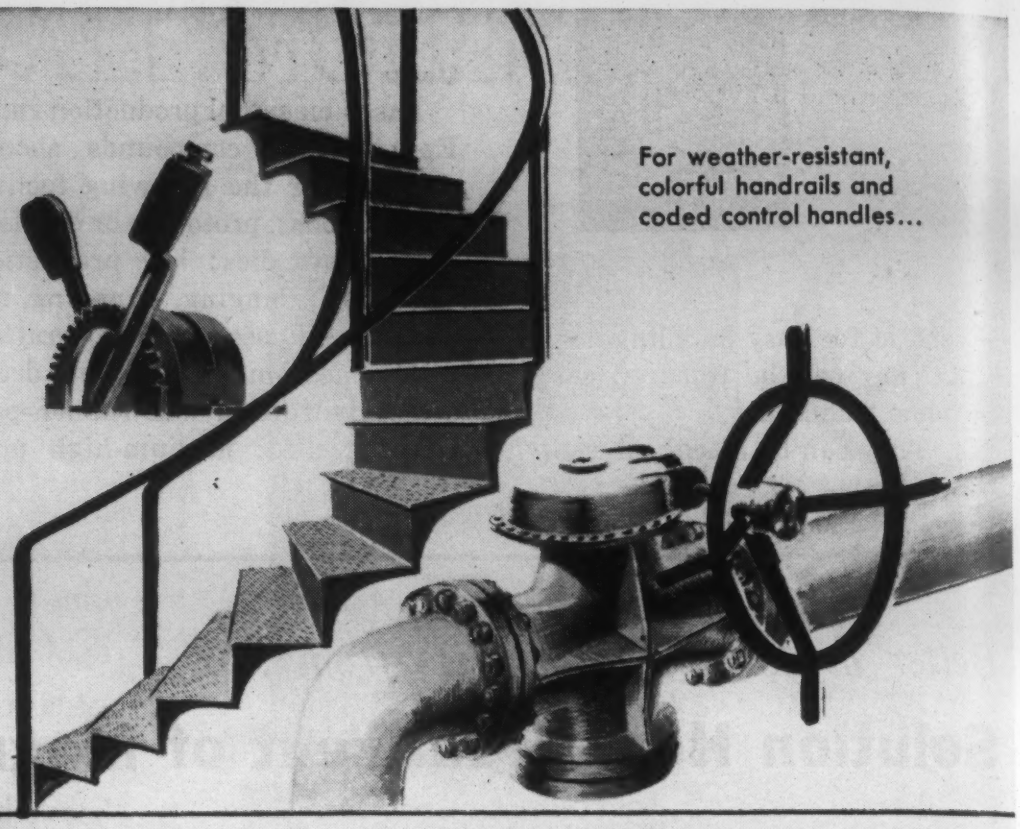
Large rotor hub plates *for helicopters (standing) weigh only 24.5 lb.*

For more information, circle No. 497

NEW WAY TO UPGRADE YOUR PRODUCTS: VINYL COATINGS



Vinyl coatings on tool handles are tough, wear-resistant, easy-on-the-hands, electrically safe. Can be applied in thicknesses up to 1/16" (60 mils) in one dip.



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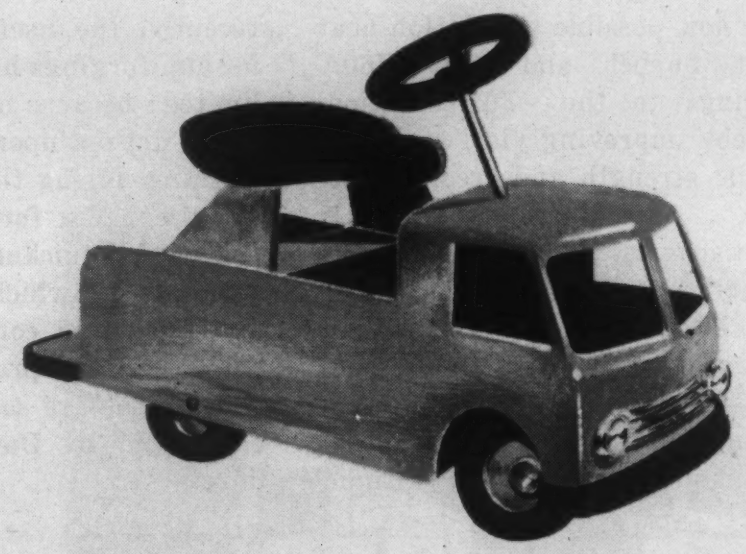
For making nonslip ladders, "silent" cutlery drawers...



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ZK60A-T5 forgings have at 300 F. In addition, the new forgings are said to be usable at temperatures as high as 900 F. Improvement in compressive yield strength is prevented by an increase in grain size resulting from exposure to the solution heat treatment.

The solution heat treatment as outlined by Dow consists of a 2-hr treatment at 930 F followed by a hot water quench and subsequent aging at 300 F for 24 hr. A protective atmosphere is recommended. According to Dow, limited testing indicates negligible distortion during treatment.

Uses

Potential applications include aircraft wheels (see photo), brake housings, fuel meter bodies, special forgings for helicopters (see photo), and certain missile structures such as internal stiffening, fins, bulkheads and others.

MECHANICAL PROPERTIES OF FORGED ZK60A ALLOY

Property ↓	Large Wheel	Small Wheel	Large Heli-copter Part
–F Temper			
Yld Str, 1000 psi.	28	33	27
Ten Str, 1000 psi.	43	46	43
Compr Yld Str, 1000 psi.....	21	27	21
–T5 Temper			
Yld Str, 1000 psi.	29	35	31
Ten Str, 1000 psi.	44	47	45
Compr Yld Str, 1000 psi.....	23	26	23
–T6 Temper			
Yld Str, 1000 psi.	40	46	40
Ten Str, 1000 psi.	48	53	49
Compr Yld Str, 1000 psi.....	21	24	26

Improved weather resistance offered by . . .

Two Acrylic Resins for Reinforced Plastics

by **M. S. Ziegler, W. H. Calkins and W. M. Edwards**

■ In order to improve reinforced plastics for outdoor uses, E. I. du Pont de Nemours & Co., Wilmington, Del., has developed what is claimed to be the "first all-acrylic laminating resins," designed for high and low pressure fabrication, respectively. Previously, small amounts of acrylic were combined with other resins. The new resins, designated Lucite 201X and 202X, are now commercially available.

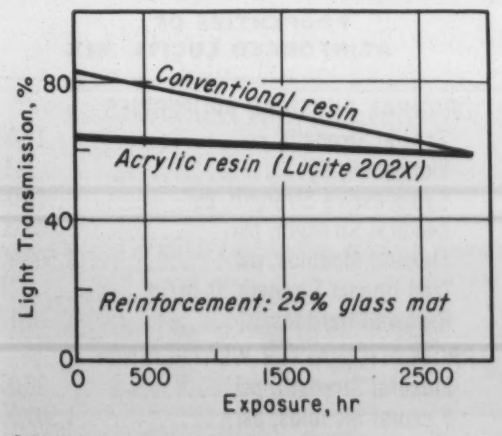
Ever since acrylic resins were first introduced in the early 1930's, they have earned a reputation for being the most weather resistant of all known plastics with the possible exception of the fluorocarbons. Acrylic resins have good optical and mechanical properties, have low water absorption, do not absorb ultraviolet radiation, and have good resistance to weak acids and alkalis. Because of these and other properties, acrylics are often used in fiber-reinforced structures that are exposed to outdoor weathering.

Du Pont engineers are currently field testing glass-reinforced laminates made of Lucite 201X and 202X acrylic resins to see how well they perform in outdoor applications. The findings are summarized below.

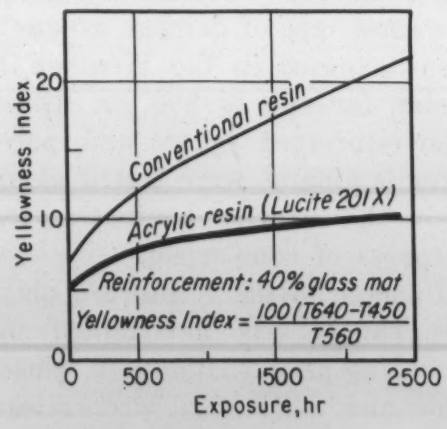
Weather resistance

Most reinforced plastics are damaged during outdoor exposure

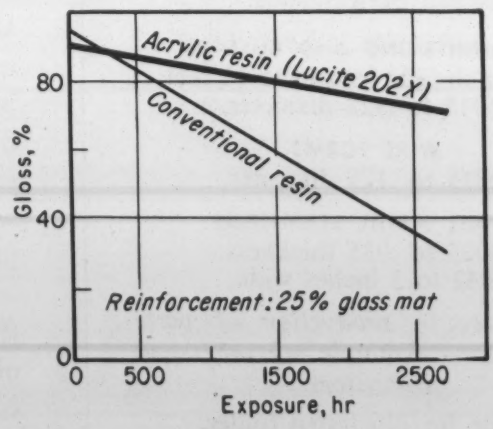
How weathering affects acrylic laminates



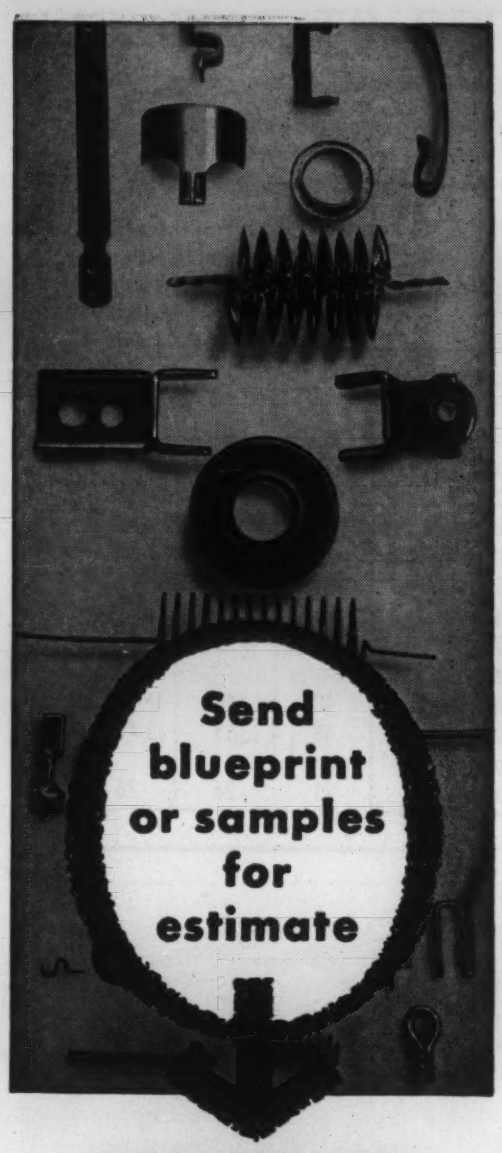
Light transmission



Color stability



Gloss retention



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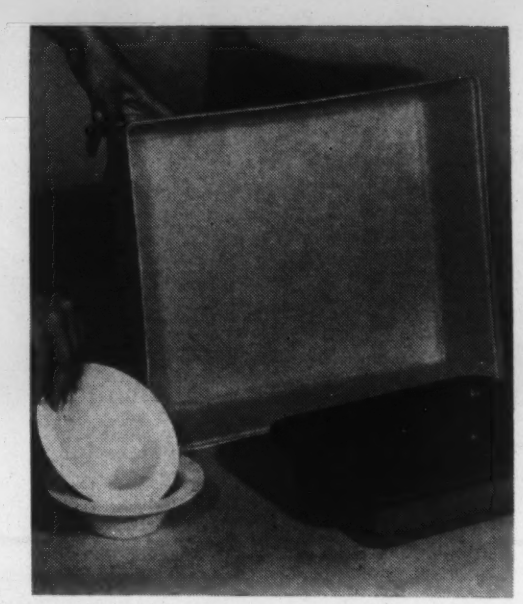

***Acrylic resins** impart excellent weather resistance to the reinforced plastics parts shown above.*

by oxidation, photochemical action caused by radiation, hydrolysis, moisture absorption, erosion, abrasion and impact. Acrylic (methacrylate) resins seem to resist these forces because they are free of benzene rings and chlorine. To determine how well acrylic resins perform upon exposure to outdoor weathering, laminates of Lucite 201X and 202X acrylic resins reinforced with glass fibers were exposed to weathering in Florida, Arizona, Michigan and Delaware. To speed up the studies, samples of the reinforced acrylic resins were exposed in an Atlas Weather-O-Meter. Although only limited outdoor exposure results are available at present, specimens exposed in Florida for one year show about the same type of damage as specimens exposed in the Weather-O-Meter for 600 to 800 hr. Glass fiber-reinforced epoxy and polyester laminates were tested along with the acrylic laminates for purposes of comparison.

Damage to the reinforced plastics panels was determined by observing any changes in gloss, color and mechanical properties; in addition, surfaces were examined visually for degradation, stress cracking, wicking and blooming. Photomicrographs were made to record the condition of the surfaces of the laminates. Results of the Weather-O-Meter tests are summarized below:

Mechanical properties of laminates of Lucite 201X and 202X acrylic resins did not change significantly after 3000 hr of accelerated weathering.

Color stability of acrylic laminates is much greater than that of epoxy and polyester laminates after accelerated exposure. Tests indicate that the change of yellowness of acrylic laminates is about half that of a variety of epoxy and polyester laminates at equal exposures.

Gloss retention studies show that acrylic laminates retain about 75% of their original gloss after 2500 hr of accelerated exposure; epoxy and polyester laminates generally retain only 40% of their original gloss.

Light transmission of acrylic, epoxy and polyester laminates drops during exposure because of wicking and degradation of the surface. Although epoxy and polyester laminates have higher initial light transmission, they suffer a greater light transmission loss during exposure than acrylic laminates.

Weathered epoxy and polyester laminates soon revealed unprotected glass fibers on the surface; badly weathered samples actually

PROPERTIES OF REINFORCED LUCITE 201X

ORIGINAL PHYSICAL PROPERTIES	
Tensile Strength, psi	12,000
Elongation, %	1.5
Compressive Strength, psi	25,000
Flexural Strength, psi	40,000
Flexural Modulus, psi	1,500,000
Izod Impact Strength, ft-lb/in.	14
Rockwell Hardness	R 123
PROPERTIES AFTER WEATHERING[a]	
Flexural Strength, psi	38,000
F'exural Modulus, psi	1,500,000
Izod Impact Strength, ft-lb/in.	13
Rockwell Hardness	R 122

[a]Aged 2500 hr in Weather-O-Meter.

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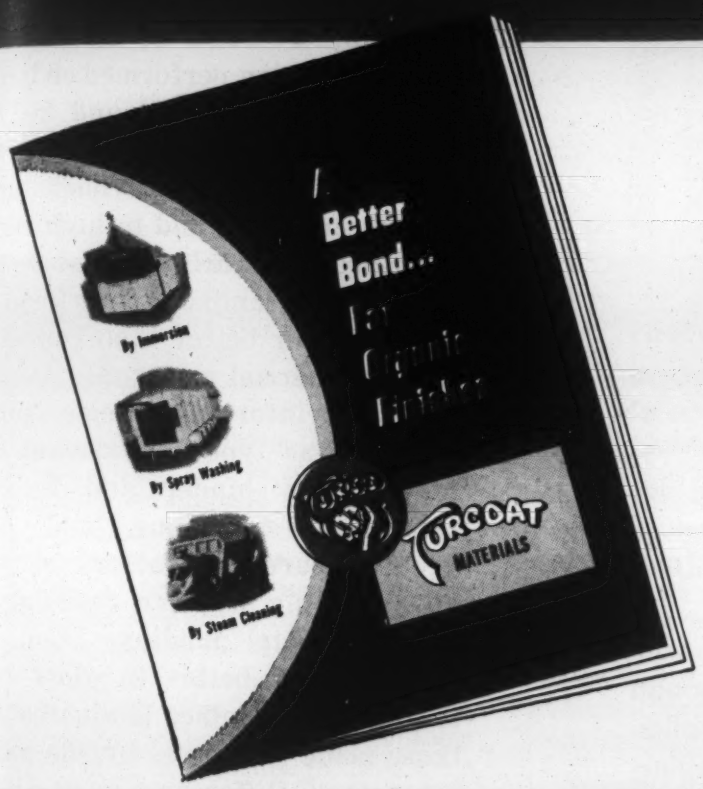

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- Diagram of how phosphating holds paint to metal
- Illustrations of what phosphating can do
- Types of coatings available
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Only Turco offers a truly full line of government approved coating materials for use in *any* conceivable processing set-up prior to the use of organic finishes. Only Turco offers a staff of 160 technically trained representatives located in all parts of the country to give immediate 'round-the-clock service. No wonder Turco is adding new phosphating accounts at a phenomenal rate. There are many reasons why, when it comes to *paint adhesion,* more and more industrial concerns are turning to the Turcoat line. The Turcoat booklet lists them all.

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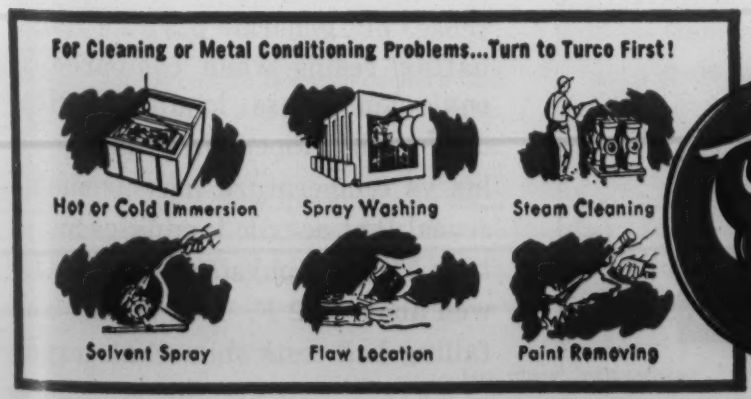

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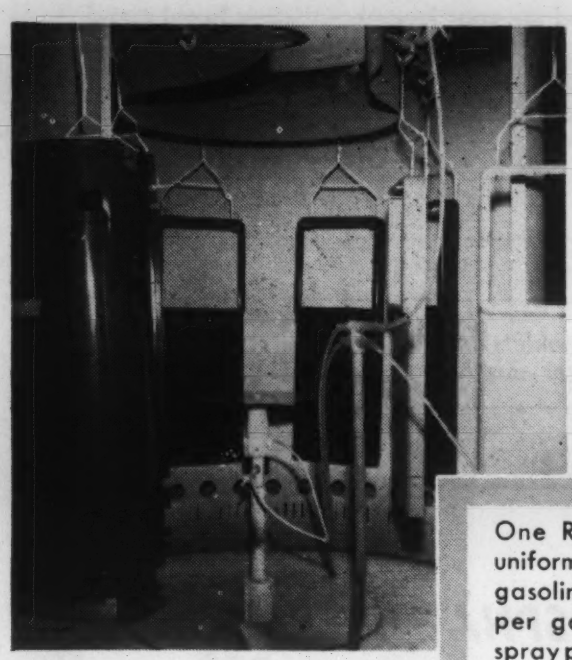

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One Ransburg reciprocating disk uniformly coats 7 complete sets of gasoline pump housings and parts per gallon of paint. Former hand spray produced only 4 sets per gallon.

● Bowser, Inc. Fort Wayne Division is continuously on the lookout for improved manufacturing methods in the production of their quality line of gasoline pumps.

That's why they modernized their finishing department . . . installed a conveyor . . . new oven . . . and replaced hand spray with one RANSBURG No. 2 PROCESS reciprocating disk unit.

RESULTS? Paint mileage increased 75% with less labor. With hand spray, they painted enough pump housings and parts for 4 pumps per gallon of paint. Now, with *Electrostatic,* they're painting 7 complete pump sets per gallon.

Where Bowser formerly needed two shifts in finishing, one shift now handles even greater production. With hand spray and limited oven facilities, they used to turn out 15 sets per hour. Now, they can paint 55 sets an hour, either prime or finish. Color changes are made quickly and easily with Ransburg equipment, and because of its efficiency in operation, maintenance cost in the paint area is cut 50%.

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Whatever your product, if it's painted, we'd like to tell you more about the worthwhile savings and advantages which can be yours with RANSBURG ELECTROSTATIC PAINTING PROCESSES. Write for our No. 2 Process brochure which cites numerous examples of electrostatic spray painting on a wide variety of products.

Ransburg ELECTRO-COATING CORP.
Indianapolis 7, Indiana

RANSBURG

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appeared fuzzy. Acrylic laminates show some increase in fiber visibility (called "blooming"), but on the whole their surfaces remain smooth. Surfacing mat was found to eliminate most of the blooming that occurred in weathered acrylic laminates.

In addition to Weather-O-Meter tests, other forms of accelerated tests have been performed on laminates of Lucite 201X and 202X; they have been subjected to boiling water, to ultraviolet and fluorescent light, and to high temperatures. In each of these tests, the acrylic laminates performed as well as or better than comparable commercial materials.

With reinforced systems, such variables as type and amount of glass, glass binder and finish, fabrication technique, and degree of cure are factors critically affecting weather resistance. Matched metal moldings seem to be somewhat better in gloss retention than contact laminates or those made in a press by the gasket method. Differences in weather resistance among acrylic laminates prepared by various fabricating techniques seem to be due primarily to differing degrees of cure and differing quantities of resin covering the surface fibers. Benzoyl peroxide without an accelerator seems to be the best curing system for laminates of Lucite 201X and 202X acrylic resins reinforced with glass fibers.

Other properties

Physical, mechanical, electrical and thermal properties of laminates of Lucite 201X and 202X are equivalent to or better than those of general purpose laminating resins when compared at equivalent glass loadings. Heat distortion temperature and modulus vs temperature measurements reveal that acrylic laminates maintain their physical properties well above 212 F. Izod impact and falling ball tests show that acrylic

SPECIAL REPORTS ON FINISHING NON-FERROUS METALS

NUMBER III—Lustrous, Corrosion-Resistant Finishing with Chemical Polishing Iridite

WHAT IS IRIDITE®?

Briefly, Iridite is the tradename for a specialized line of chromate conversion finishes. They are generally applied by dip, some by brush or spray, at or near room temperature, with automatic equipment or manual finishing facilities. During application, a chemical reaction occurs that produces a thin (.00002" max.) gel-like, complex chromate film of a non-porous nature on the surface of the metal. This film is an integral part of the metal itself, thus cannot flake, chip or peel. No special equipment, exhaust systems or specially trained personnel are required.

Chromate conversion coatings are widely accepted throughout industry as an economical means of providing corrosion protection, a good base for paint and decorative finishes for non-ferrous metals. Certain of these coatings also possess chemical polishing abilities that have luster-producing, as well as corrosion-inhibiting, effects on zinc and cadmium plate, zinc die castings and copper alloys. However, continued developments in this field have been so rapid that many manufacturers may not be completely aware of the breadth of application of this type of finish. Hence, this discussion of the many ways in which this chemical polishing characteristic can be used in final finishing or pre-plating treatments to produce a lustrous appearance with distinct display and sales appeal and appreciable savings in cost. Report I on decorative, corrosion-resistant finishes and Report II on paint base corrosion-resistant finishes are available on request.

The degree of luster possible on a surface is a function of the degree to which the surface can be smoothed. Leveling to provide a smooth surface can be achieved by mechanical or chemical means, or a combination of these, depending upon the luster desired and the original condition of the metal. Chemical polishing effectively imparts luster otherwise difficult and costly to obtain. For this reason, it is often used to supplement or entirely replace mechanical polishing, depending upon the application and the original condition of the metal. Chemical polishing has the additional advantage of providing overall treatment of the submerged part. It reaches into even the deepest corners and recesses that are otherwise inaccessible. Certain of the Iridites are specifically designed to perform this chemical polishing operation. Also, they provide corrosion protection as do all Iridites, thus may be used as a final finish or a pre-plating polish.

If Iridite is to be used as a final finish, in contrast to pre-plating treatment, the chromate conversion coating generated is allowed to remain, providing good corrosion resistance. Color inherent in these Iridite films ranges from a yellow cast to yellow iridescent. These coatings may be used without further treatment where this color is acceptable and good corrosion resistance is desired. Further, these basic coatings can be tinted by dyeing. Among the dye tints available are shades of red, yellow, blue and green. If desirable, the basic coatings can also be modified by a bleach dip leaving a clear bright or blue iridescent finish. In all cases bleaching reduces corrosion resistance.

As examples of this type of final finishing, Iridites #4-73 and #4-75 (Cast-Zinc-Brite) make possible for the first time, lustrous chemical polishing of the as-cast surface of zinc die castings. Thus, in many cases, sizeable savings in finishing cost are realized by elimination of plating costs. This economical method can be used on tools, appliance parts, toy pistols, locks and many other small castings. Another example is the treatment of copper and brass parts, such as welding tips, to eliminate buffing and provide additional corrosion resistance. In many cases, handling costs are reduced appreciably by replacing piece-part handling with bulk processing. Still another example of the use of this chemical polishing and protective quality of Iridite is a simple system of zinc plate, Iridite and clear lacquer instead of more costly electroplated finishes. Typical of this type of lustrous finish are builders hardware and wire goods.

As a pre-plating treatment, in contrast to final finishes, Iridite can be used to chemically polish zinc die castings or copper prior to plating. In such cases, Iridite should be applied as an in-process step, so that the protective film is removed before the plating cycle. The savings in handling, material and labor costs are obvious. This process has made it practical to plate chrome directly over copper on steel, conserving nickel, yet producing a lustrous chrome finish. Used after stripping faulty plate in reprocessing zinc die castings, Iridite restores luster to the casting, thus making possible replating without blistering.

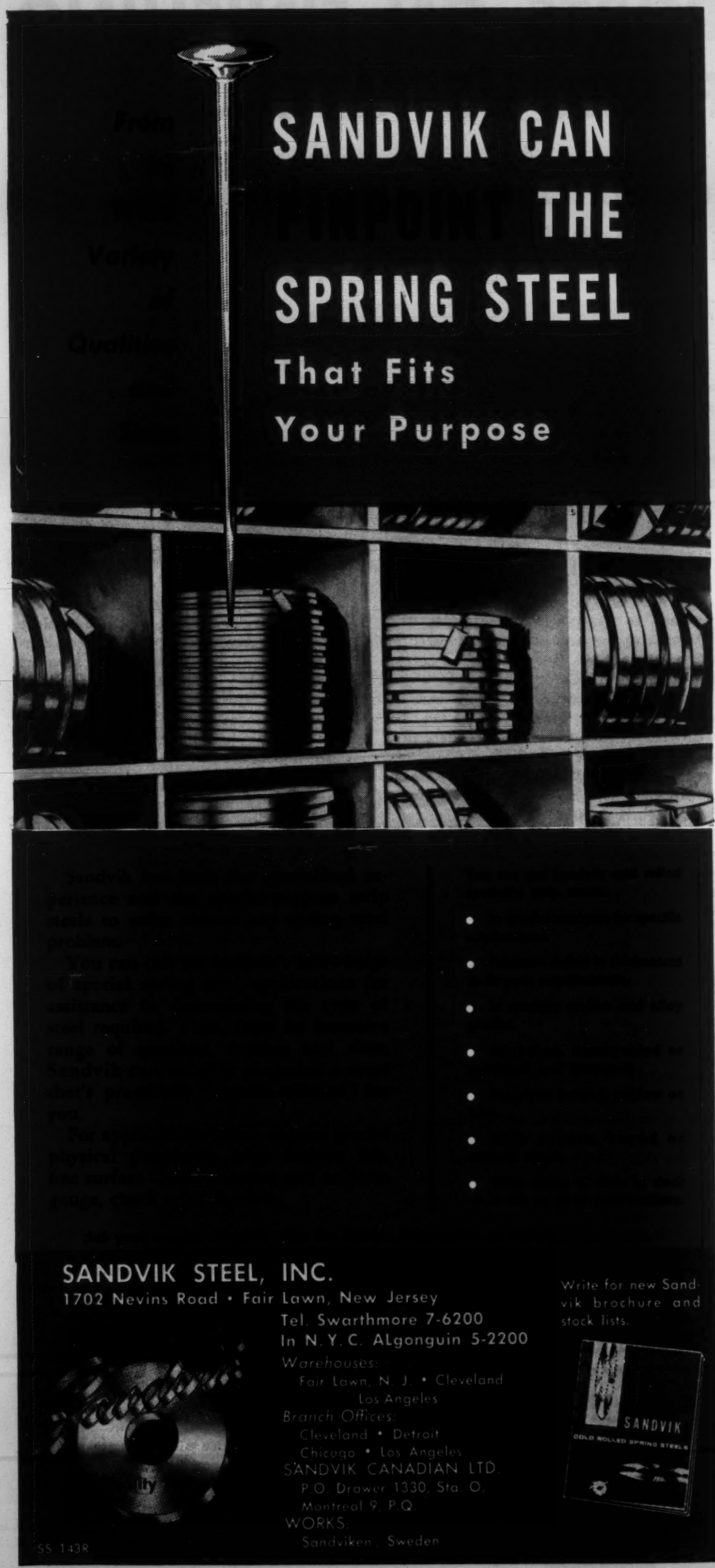
Other Iridite finishes are available to produce maximum corrosion resistance, a wide variety of decorative finishes and excellent bases for paint on all commercial forms of the more commonly used non-ferrous metals. As a final finish, appearance ranges from clear bright to olive drab and brown and many films can be bleached or dyed. As a paint base Iridite provides excellent initial and retentive paint adhesion and a self-healing property which protects bare metal if exposed by scratching. Iridites have low electrical resistance. Some can be soldered and welded. The Iridite film itself does not affect the dimensional stability of close tolerance parts.

Iridites are widely approved under both Armed Services and industrial specifications because of their top performance, low cost and savings of materials and equipment.

You can see then, that with the many factors to be considered, selection of the Iridite best suited to your product demands the services of a specialist. That's why Allied maintains a staff of competent Field Engineers—to help you select the Iridite to make your installation most efficient in improving the quality of your product. You'll find your Allied Field Engineer listed under "Plating Supplies" in your classified telephone book. Or, write direct and tell us your problem. Complete literature and data, as well as sample part processing, is available. Allied Research Products, Inc., 4004-06 East Monument Street, Baltimore 5, Maryland.

(Adv.)

For more information, turn to Reader Service card, circle No. 398



laminates have exceptional resistance to damage by impact.

Generally speaking, acrylic laminates made of Lucite 201X and 202X have good resistance to organic acids, alcohols, aliphatic hydrocarbons and mild bleaching agents. The resins are attacked by esters, ketones, aromatic hydrocarbons and some chlorinated hydrocarbons.

The light transmittance of unpigmented acrylic laminates 1/16 in. thick and containing 25% glass is about 65%. This transmittance is nearly all diffused, giving excellent image hiding power and eliminating glare. Individual fibers are comparatively visible in acrylic laminates because of the large differences in the refractive indices of the resin and the glass fibers.

Other properties of Lucite 201X and 202X acrylic resins:

1. Lucite 201X and 202X resins have a smaller decrease in viscosity with increased temperature than polyester resins.

2. Both resins wet fabrics and mats without difficulty.

3. Both resins have a long shelf life; in one test a drum of the resin showed negligible change in viscosity and color during outdoor storage for one year.

4. Shear strength measurements show that the strength of the bond between glass fiber and resin

CHEMICAL RESISTANCE OF ACRYLIC LAMINATES[a]
(Weight Change, %)

Acetone (100%)	−2.5
Acetic Acid (5%)	+2.3
Ammonium Hydroxide (10%)	+2.2
Carbon Tetrachloride (100%)	+2.9
Distilled Water (100%)	+0.9
Ethyl Alcohol (100%)	+7.5
Ethylene Dichloride (100%)	Dissolved
Hydrogen Peroxide (3%)	+1.6
Nitric Acid (10%)	+10.0
Sodium Chloride (10%)	+1.2
Sodium Hydroxide (10%)	+1.0
Sulfuric Acid (3%)	−1.0
Sulfuric Acid (30%)	+0.8
Toluene (100%)	−1.3

[a]Aged 7 days at room temperature.

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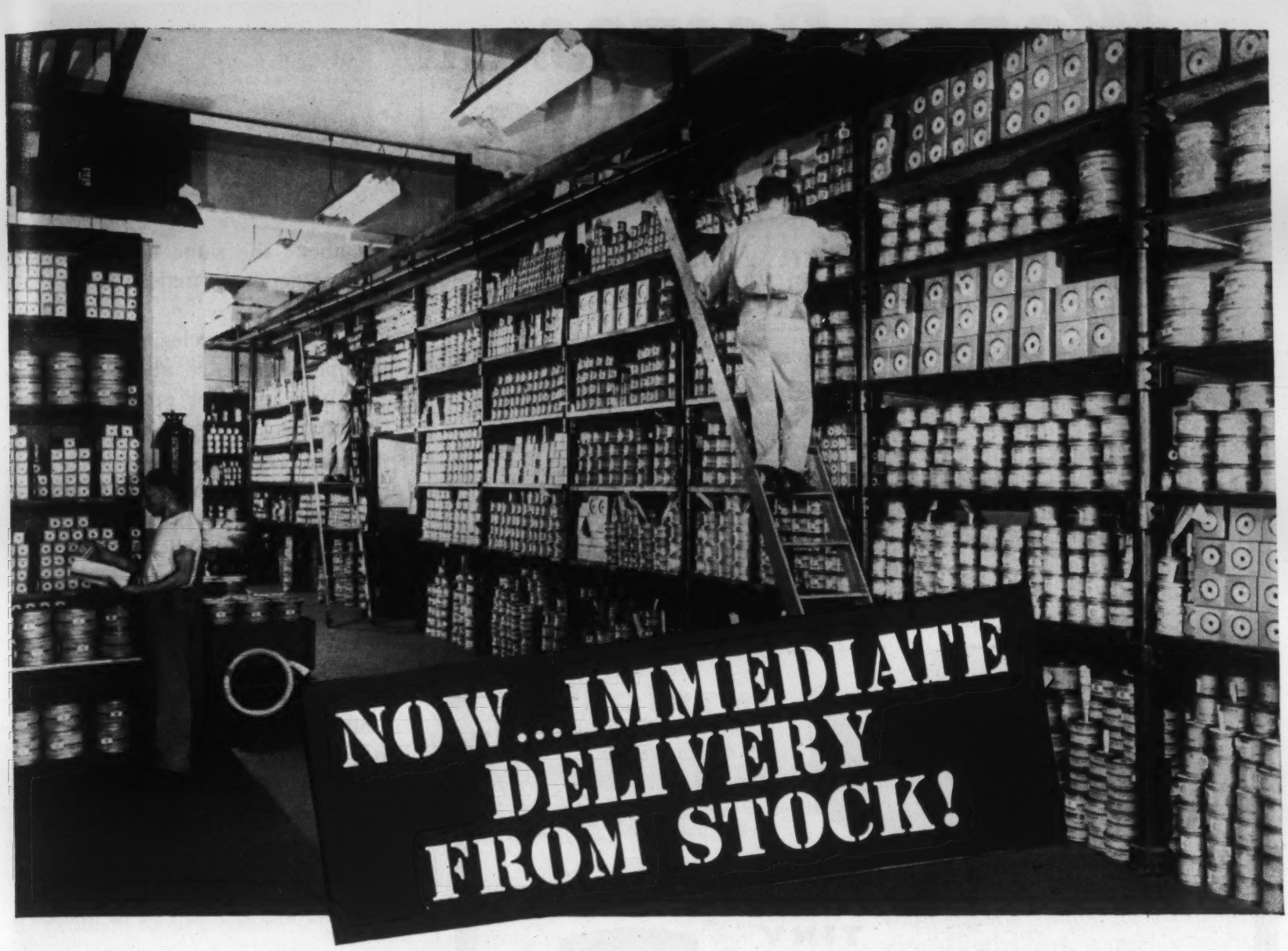

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GRADE "A" NICKEL	12 wire sizes from .0025 to .091
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INCONEL	3 wire sizes from .0253 to .050

STAINLESS STEEL	
Type 304	24 wire sizes from .0016 to .164
Type 316	6 wire sizes from .007 to .0135
Type 330	25 wire sizes from .0063 to .144
NICHROME*	65 wire sizes from .0007 to .289
NICHROME* V	62 wire sizes from .00045 to .289
CHROMAX*	35 wire sizes from .0031 to .258
KARMA*	36 wire sizes from .0005 to .036
ADVANCE*	49 wire sizes from .0008 to .258
MANGANIN	37 wire sizes from .001 to .1285
LOHM*	29 wire sizes from .001 to .182
MIDOHM*	28 wire sizes from .00175 to .182
30 ALLOY	28 wire sizes from .0015 to .182

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As low as 10 days for	
COLD DRAWN MONEL	wire sizes from .001 to .1875
GRADE "A" NICKEL	wire sizes from .001 to .1875
COLD DRAWN INCONEL	wire sizes from .001 to .1875
R MONEL	wire sizes from .0285 to .204
As low as 7 days for	
STAINLESS STEEL	wire and ribbon

Types: T-302, T-304, T-305, T-316, T-430, T-446

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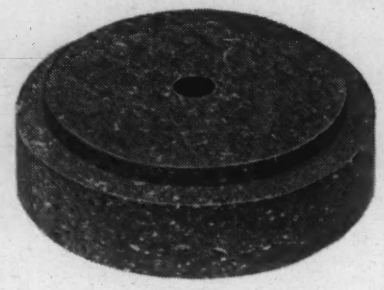

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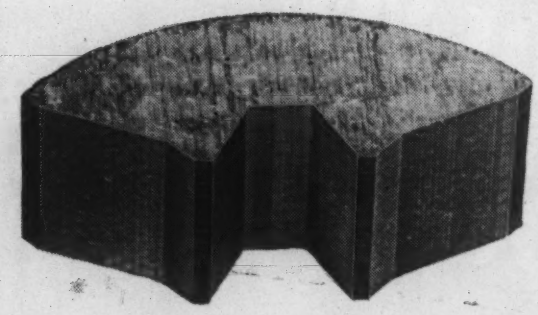

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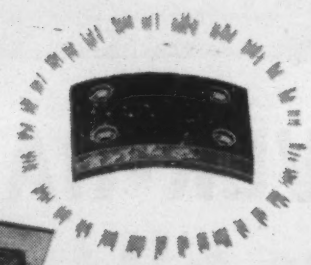

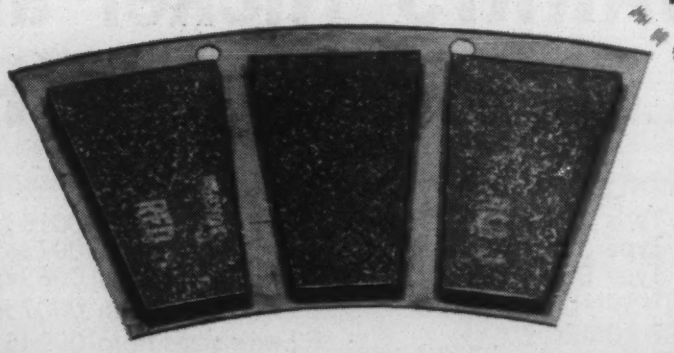

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DIVISION OF THE **Firestone** TIRE AND RUBBER CO.

Industrial and Automotive Brake Blocks and Linings • Transmission Linings • Special Clutch Facings • Vibration Controls • Sheet Packing

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is about the same as for conventional general purpose laminating resins.

5. Molding cycles, pressures and temperatures are about the same as those used for general purpose laminating resins.

Dacron reinforcement

In addition to glass fibers the resins may be reinforced with Orlon and Dacron fibers. Orlon- and Dacron-reinforced acrylic resins can be heated to their softening point and postformed at low pressures to deeply drawn shapes. (For more information on Orlon- and Dacron-reinforced acrylics, see MATERIALS IN DESIGN ENGINEERING, Nov '57, p 210).

Based on a paper presented at the 13th conference of the Reinforced Plastics Div. of the Society of the Plastics Industry, Inc., held Feb 4-6 in Chicago. The authors are associated with E. I. du Pont de Nemours & Co., Inc.

How Corrosion Affects AISI 201, 202 Steels

The corrosion resistance of manganese-containing stainless steels is almost as good as that of nickel-containing stainless steels. Because nickel is often in short supply it has become necessary to develop manganese stainless steels that can be substituted for nickel stainless steels in time of emergency; outstanding among the manganese-containing stainless steels are AISI 201 and 202.

Recently, Robert D. Merrick, supervisor, Corrosion Engineering Section, Esso Research & Engineering Co., and C. L. Mantell, chairman, Dept. of Chemical Engineering, Newark College of Engineering, conducted a survey of published articles dating back to 1920 to find information on the corrosion resistance of chromium-manganese austenitic stainless steels.

The authors divide their study into two sections: the first shows the effect of substituting man-

Excellent Formability of Magnesium Inspires Simplified Designs

Deep drawn components, for example, replace multipart assemblies

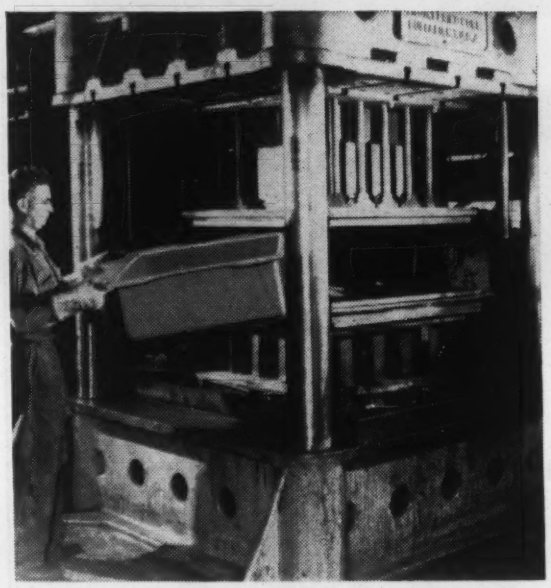
IN forming magnesium alloys, there's often more than one way to do the job. Matter of fact, the excellent shop characteristics of this remarkable metal permit it to be formed by almost every forming method known. The use of magnesium makes it possible to simplify complex designs that otherwise would require several separate parts and numerous production operations. Its high strength-to-weight ratio permits a choice of lighter design without loss of strength, or stronger design without weight penalty. Magnesium's hexagonal crystalline structure means excellent workability at elevated temperatures which offers the following advantages:

1. Deeper single draws than with other metals.
2. Reduced tooling costs.
3. Minimized springback.
4. Less wrinkling.
5. Better tolerance control by temperature adjustment.

These considerations, added to the fact that magnesium is the metal that's easiest to machine and fabricate, mean substantial cost savings in design and production.

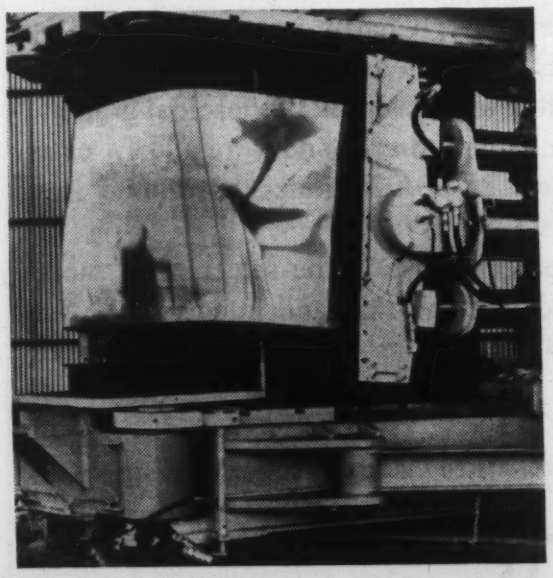
Here are a few of the forming methods that yield these advantages:

DEEP DRAWING AND PRESSING. Magnesium parts are made by both deep and shallow drawing or pressing. Magnesium sheet alloys in the annealed condition may be cold drawn with a reduction of 15 to 25 per cent. Hot drawing, however, increases the reduction up to almost 70 per cent. Deeper single stage draws can be made in magnesium (when heated) than in other metals.



LARGE DEEP DRAWN PARTS can be made in a single step with magnesium alloys.

STRETCH FORMING. This highly flexible method is used in shaping large area magnesium sheets. Jaws hold opposite edges in tension while a male block or punch stretches the metal beyond its elastic range. Stretching the entire work piece insures uniform pressure at all points of contact during forming. This results in even distribution of work hardening and the elimination of localized strains. Changes in cross sectional dimensions are more uniform than with other forming methods. Hot stretch forming results in a minimum of springback.



STRETCH FORMING with magnesium alloys provides uniform properties on large sections.

RUBBER FORMING. For relatively small quantities of shallow parts, this process can be put to good use. Both hot and cold forming can be done. Dies cost much less than for other methods and design changes are easy and inexpensive to make. The principle of rubber forming is simple. A pad of rubber powered by a ram forces the work blank to assume the contour of a die directly below it.

DROP HAMMER FORMING. This method is often used for asymmetrical shapes with shallow draws, or cases where special springback control is required. Drop hammer forming is not a precision method, hence close tolerances are not possible.

SPINNING. When a number of small parts are needed, spinning is often the most economical way to accomplish the job. However, as many as five thousand parts can sometimes be spun for less cost than when made by press forming. Spinning involves no dies, and the cost of chucks and spinning tools is relatively inexpensive.

EXTRUSION FORMABILITY. Production bending of extrusions is done on standard rolls, in mating dies, in stretch forming machines, or other specialized bending equipment. If the forming is severe, extrusions are formed hot. The bending of complex extrusions requires that bend radii be established for a given shape by the shop for its particular application.

FORMING MAGNESIUM, a 130-page handbook, covers all methods of forming discussed above, plus blanking and cutting, bending, dimpling, forging, hand forming, selection of alloys and assembly protection. Includes numerous tables on properties at temperatures, dimensions, etc. For your copy contact a Dow sales office or write THE DOW CHEMICAL COMPANY, Midland, Michigan, Dept. MA 1452J.

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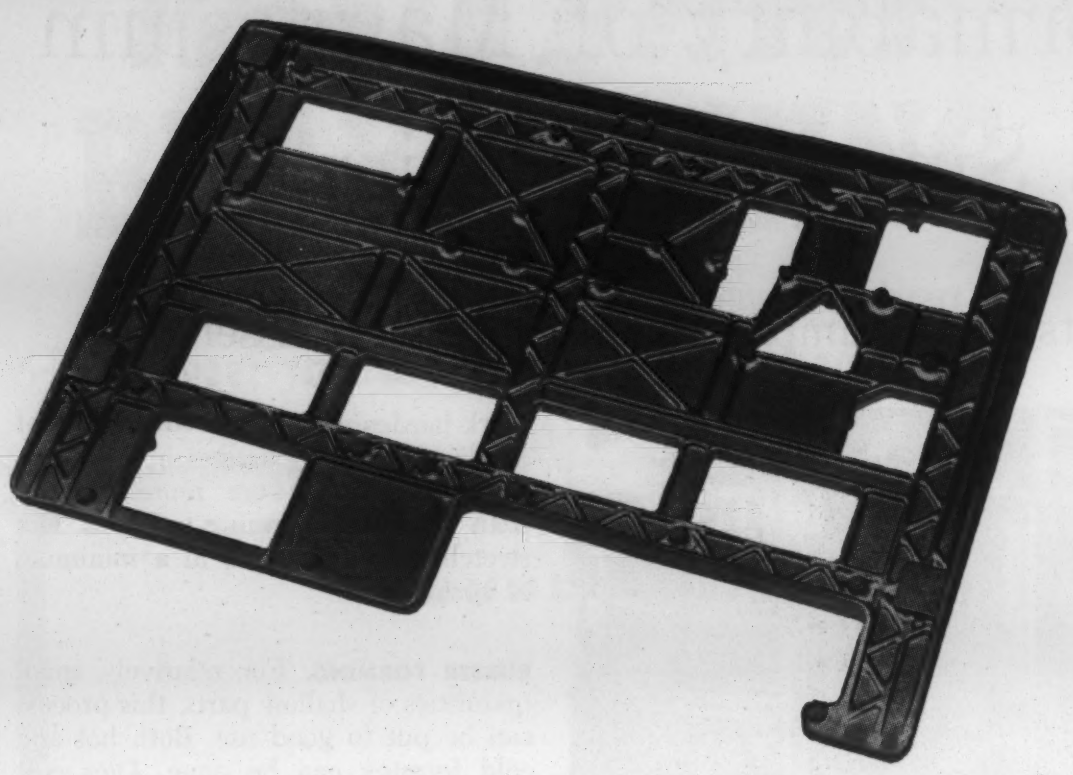

DUCTILITY

A CASE IN POINT—This ninety-six pound casting was made for the National Cash Register Co. of Nodulite®, Hamilton Foundry's ductile iron. The casting forms the base for the new Post-Tronic Accounting Machine. It measures 37½" by 23½" with sections varying from ¼" to 1½". Ductile iron was chosen for this part because of its ductility, dimensional stability, rigidity, and machinability.

Ductile iron has most of the engineering advantages of steel yet it can be designed with the same flexibility and cast with the same procedures used for gray iron. It has high strength: up to 120,000 psi minimum tensile strength in standard grades. It is tough: Charpy impact strengths up to 115 ft.-lbs. in standard grades. It is ductile: elongation is possible up to 25% after short time annealing. And it is wear resistant: spheroidal graphite particles provide for self-lubrication. Hamilton Foundry regularly casts 60-45-10, 80-60-03, 100-70-03, and 120-90-02 grades of ductile iron as well as high alloy Ductile Ni-Resist.

When new and unusual design problems arise in the selection of metal and the casting of parts, you will find that the skill and integrity of your foundry is your best insurance that specifications—and delivery schedules —will be met.

GRAY IRON • ALLOYED IRON • MEEHANITE® • DUCTILE (NODULAR) IRON • NI-RESIST • DUCTILE NI-RESIST • NI-HARD

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What's new IN MATERIALS

ganese for nickel in various types of environments; the second covers the corrosion resistant properties of the manganese-containing austenitic stainless steels, AISI types 201 and 202. What they found is summarized below.

Manganese vs nickel

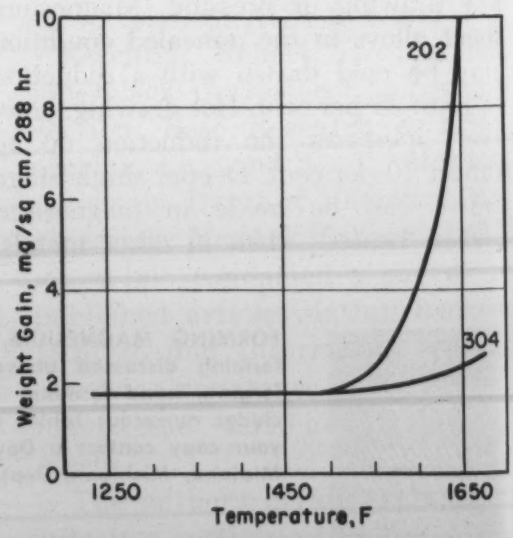
Nitric acid: Stainless steels containing from 4 to 8% manganese show no corrosion in boiling nitric acid. Above this manganese content, however, the corrosion rate increases, but even at 18% manganese the increase is slight.

Most data for nitric acid was obtained from a boiling 65% solution. These conditions are critical for austenitic stainless steels and are usually used to determine resistance to intergranular corrosion (Huey test). For this evaluation, only data taken from fully annealed samples were used.

Phosphoric acid: Manganese below 9% has no effect on the corrosion resistance of a 17-18 chromium, 4-5% nickel alloy in 10% boiling phosphoric acid. At greater concentrations manganese increases the corrosion rate of the alloy. This effect is similar to that experienced with nitric acid.

Sulfuric acid: From the data available, it appears that the substitution of manganese for nickel does not produce an alloy with comparable corrosion resistance in sulfuric acid.

Acetic acid: The addition of



Oxidation rates *of type 202 and 304 stainless steel alloys.*

BRIDGEPORT BRASS
COPPER ALLOY BULLETIN

Bridgeport Brass Co. — Reporting New Developments in Copper-Brass Alloys and Metalworking Methods

Duronze #707 Has Many Applications

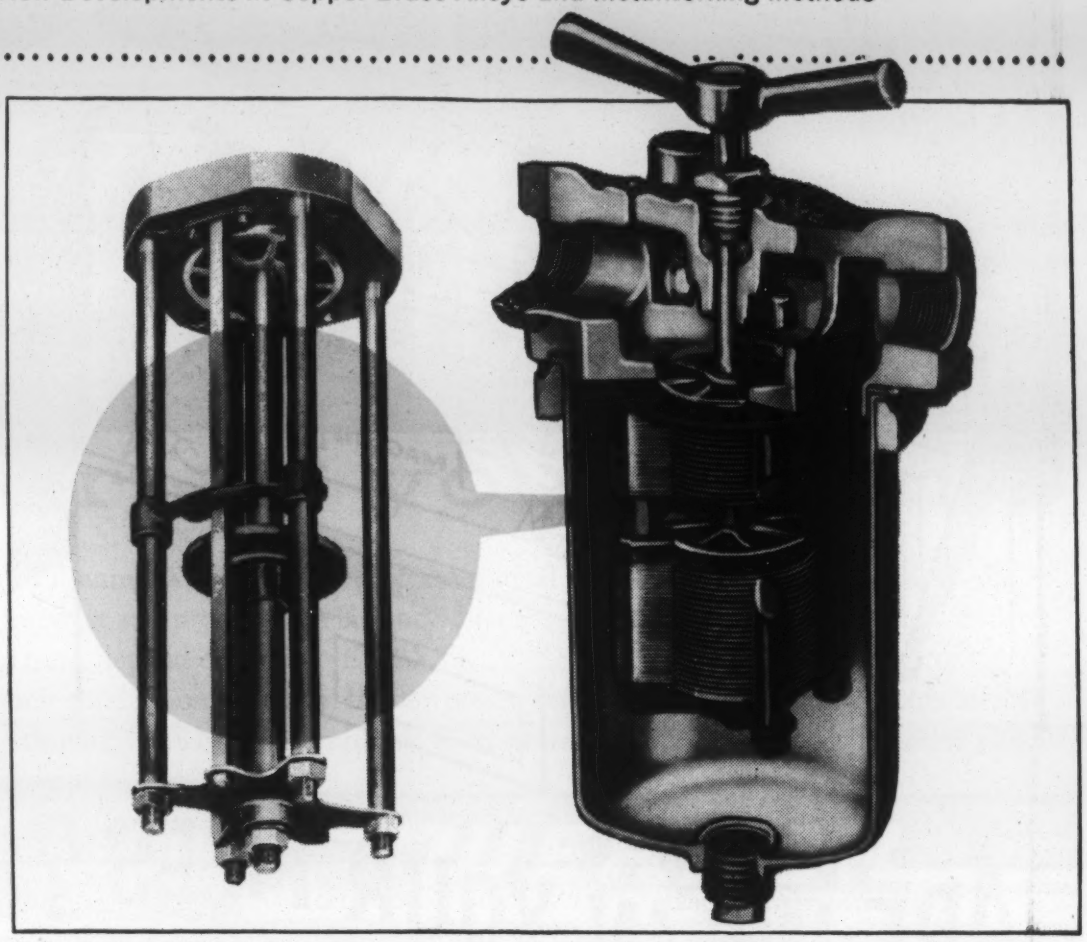
by M. A. BUELL
Chief Staff Metallurgist

Duronze #707 is a truly versatile aluminum-silicon bronze alloy. Its combination of properties—good machinability, corrosion and wear resistance, high tensile strength, low coefficient of friction, and excellent fatigue resistance—is ideally suited to many product requirements.

It can be used advantageously, for instance, as components for solderless wire cable connectors and pole line hardware; for nuts, bolts and studs; and for compression fittings on oil and gas lines in aircraft. Since Duronze supporting sleeves in compression fittings distribute vibration and fatigue stresses over a greater area of the tube than is possible with ordinary fittings, serious breaks in the tube lines can be prevented.

Still another important property offered by Duronze #707 is its high tensile and yield strength in its annealed condition. This makes it especially suitable for hot working into gears, pinions, valve parts, rollers, etc. The friction between Duronze #707 and steel is less than that between steel and steel. It can thus be used to replace steel or cast-bronze parts and generally give longer life. Duronze #707 hot-forgings include suspension clamps and terminals for hollow cable jumper and strain connectors; valves; parts for oxyacetylene torches; and marine hardware.

Duronze #707 is just one of five different aluminum and silicon bronze alloys made by Bridgeport. Each has outstanding combinations of mechanical and physical properties designed to meet specific engineering needs. For more information and test samples call your nearest Bridgeport Sales Office.



Unique Continuous-Flow Filter Uses Duronze Backbone For Strength and Corrosion Resistance

The unusual design of the Auto-Klean® Filter manufactured by Cuno Engineering Corporation, Meriden, Conn., permits it to be cleaned continuously, either manually or by motor, without costly interruption of flows or service.

Filtration is obtained by passing the fluid between wheel-shaped metal discs placed edgewise to the flow. These discs are separated by spacers of predetermined thickness so that solids larger than the spacers cannot pass through. Extending into the slots between the discs are the knifelike cleaner blades. Filtration down to 1 micron is possible.

Duronze #707 Backbone

The mounting of the filter disc and cleaner-blade assembly is vital to efficient operation. To help insure accurate alignment, Cuno relies extensively on Bridgeport Duronze #707 (Aluminum-Silicon Bronze Alloy) to form the main spindles which are the backbone of the assembly. Strong, corrosion resistant and easily machined, Duronze #707 has all the qualities needed for the rigid requirements of this application.

Duronze #707 for Engineering Jobs

Duronze #707 is one of a number of engineering alloys made by Bridgeport to meet the needs of durable, hard-working products. Its high strength and corrosion resistance, plus good machinability are important advantages from both production and economy standpoints. It will pay you to see how Duronze can meet your requirements. Your Bridgeport Salesman, backed by Bridgeport Technical Service, will be glad to help you. Call him today.

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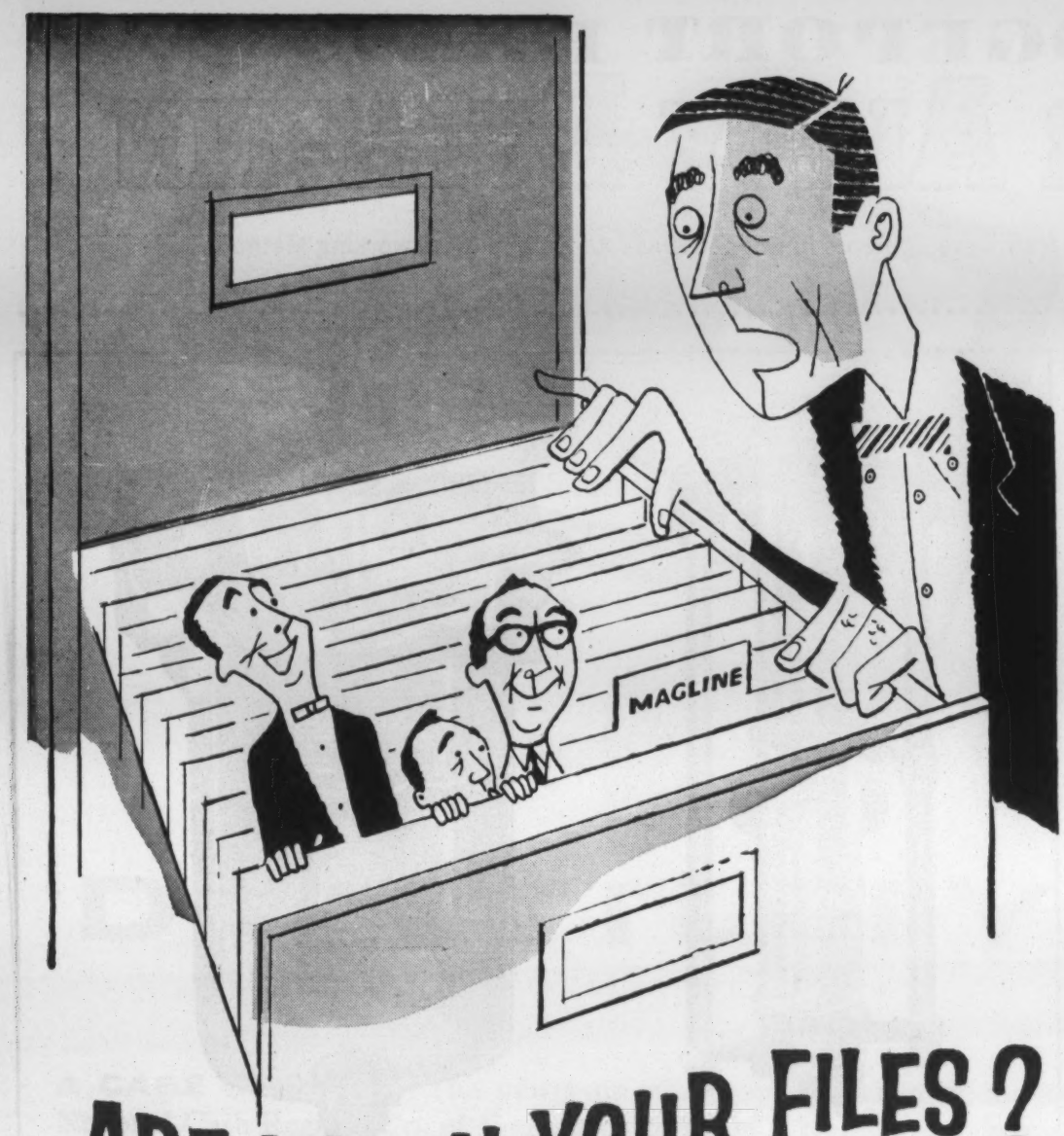

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AS A DEPENDABLE SOURCE FOR MAGNESIUM PARTS AND PRODUCTS

Whether you plan the development of a new product, or are seeking ways to further improve existing ones, you will be interested in the many new avenues which are open to the design engineer who includes magnesium in his basic planning.

Magline Inc.—one of America's leaders in magnesium—has prepared a descriptive new bulletin, expressly outlining for designers and engineers, the company's services as a reliable, experienced source for magnesium castings, fabrication and complete production. Specialists in magnesium exclusively, Magline's background and experience will serve you well in three important ways: (1) Objectively searching out ways to improve your product through the application of magnesium; (2) Assisting in the design and development phases; (3) Producing the required parts and components in any quantity, to your exact specifications. May we send you a copy of Bulletin No. 50.

MagLine

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CANADIAN FACTORY: MAGLINE OF CANADA, LIMITED, RENFREW, ONTARIO

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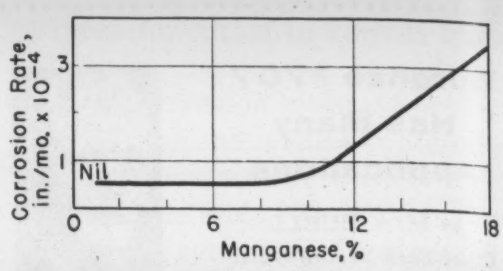
What's new IN MATERIALS



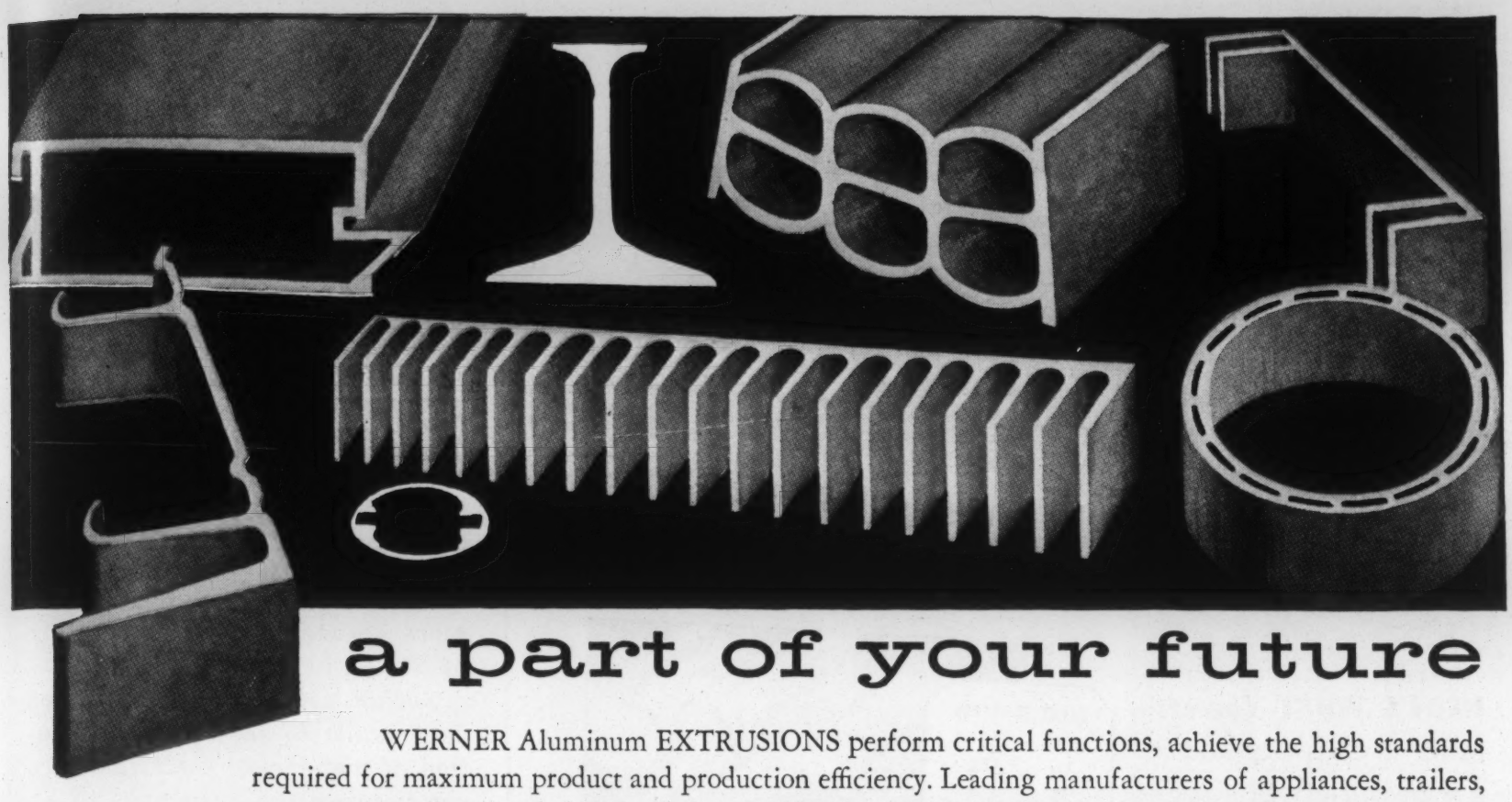
***How manganese** affects corrosion of 17-18 chromium, 4-5% nickel alloy in 10% boiling phosphoric acid.*

manganese to a 17-18 chromium, 4-5% nickel alloy appears to decrease corrosion resistance. Chromium has a much greater effect on resistance to acetic acid than manganese. Increasing chromium from 16 to 19% decreases the corrosion rate from 0.008 to 0.00004 in. per month. Most published data indicate that type 201 and 202 alloys and the low nickel alloys are as resistant to acetic acid as are the 18 chromium-8% nickel alloys and 12% chromium alloys.

Lactic acid: Manganese, in concentrations of less than 11%, has no effect on the corrosion resistance of a 17 chromium-4% nickel alloy in boiling 50% lactic acid. At concentrations greater than 11%, manganese greatly increases the corrosion rate.

Atmospheric corrosion: Although there is much information published on atmospheric corrosion, there are few quantitative data available on the corrosion resistance of various compositions. One report indicates that types 201 and 202 alloys and the high chromium-high manganese stainless steels are just as resistant to both industrial and marine atmospheres as types 301, 302 and 304 stainless steels.

Oxidation resistance: Published data show that the addition of 10 to 14% manganese to a 20% chromium alloy increases the oxidation rate considerably. A 10 manganese-18% chromium alloy is inferior to a 9 nickel-19% chromium alloy at 1835 F, but the alloy is



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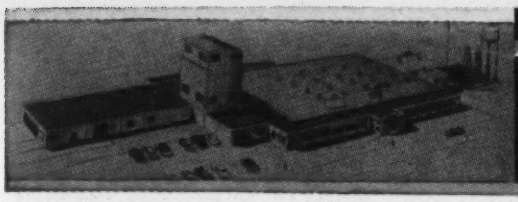

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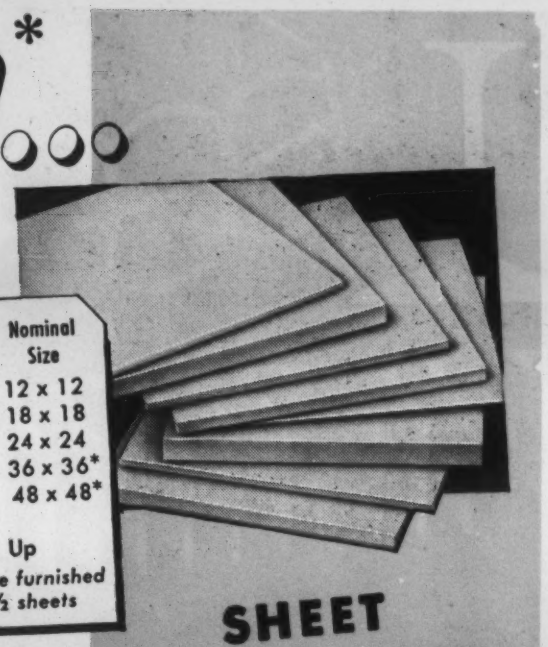
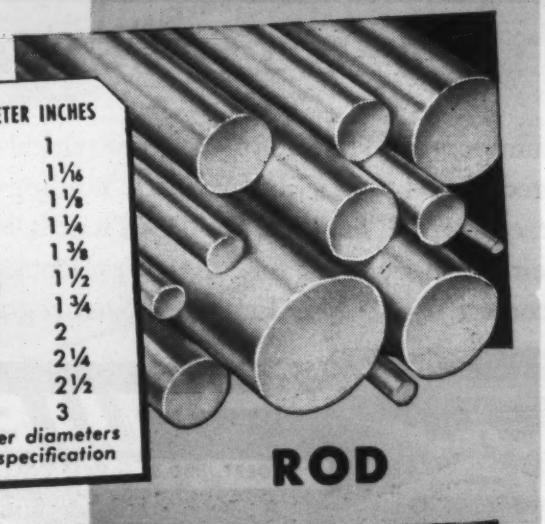


Thickness Inches	Nominal Size
1/16	12 x 12
3/32	18 x 18
1/8	24 x 24
3/16	36 x 36*
1/4	48 x 48*
3/8	
1/2 & Up	

* Can be furnished in ½ sheets

SHEET



DIAMETER INCHES	
1/4	1
5/16	1 1/16
3/8	1 1/8
7/16	1 1/4
1/2	1 3/8
9/16	1 1/2
5/8	1 3/4
3/4	2
7/8	2 1/4
	2 1/2
	3

Other diameters on specification

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TYPICAL SIZES INCHES	
O. D.	I. D.
3/8	1/4
1/2	3/8
3/4	1/2
1	3/4
1 1/2	1
2 1/2	1 1/2
3	1 3/4

TUBING

Characteristics of Teflon

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Completely inert.

ELECTRICAL
Very high dielectric strength.
Extremely low power factor.

THERMAL
Temperature range
−300° to +500° F.

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For more information, turn to Reader Service card, circle No. 407

What's new IN MATERIALS

COMPOSITION OF TYPES 201 AND 202 (%)

Type →	201	202
Carbon	0.15 max	0.15 max
Chromium	16.0-18.0	17.0-19.0
Nickel	3.5-5.5	4.0-6.0
Manganese	5.5-7.5	7.5-10.5
Nitrogen	0.25 max	0.25 max

more resistant at a temperature of 2000 F.

Sulfur corrosion: The limited data available show the substitution of manganese for nickel does not improve the resistance of an alloy to sulfur corrosion; in fact, manganese appears to decrease resistance to sulfur attack.

Intergranular corrosion: Certain published data show that for immunity from intergranular attack, the carbon content of manganese-containing steels should be less than 0.025% if the sum of the manganese and nickel content is 14%.

Types 201, 202

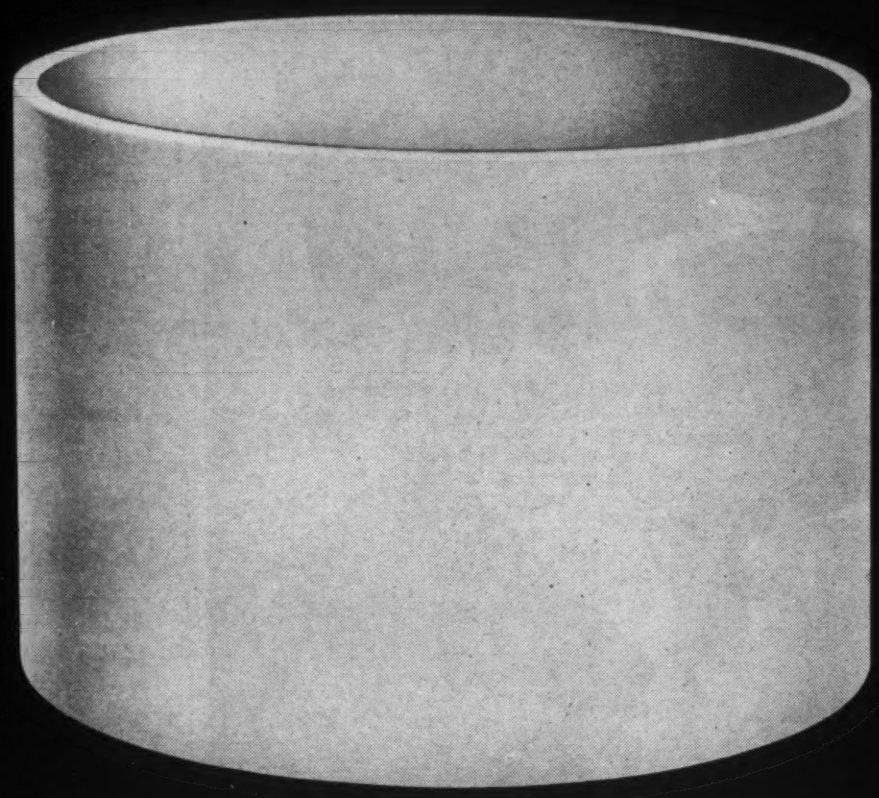
Merrick and Mantell report that the manganese-containing austenitic stainless steels, types 201 and 202 appear to resist attack by a number of chemicals, their resistance being similar to that of types 301 and 302. Type 201 is intended as a substitute for type 301 and type 202 as a substitute for type 302. Types 201 and 202 stainless steels are intended for use in such consumer items as appliances, automotive parts, flatware, plumbing fixtures, dairy equipment, fasteners and hardware.

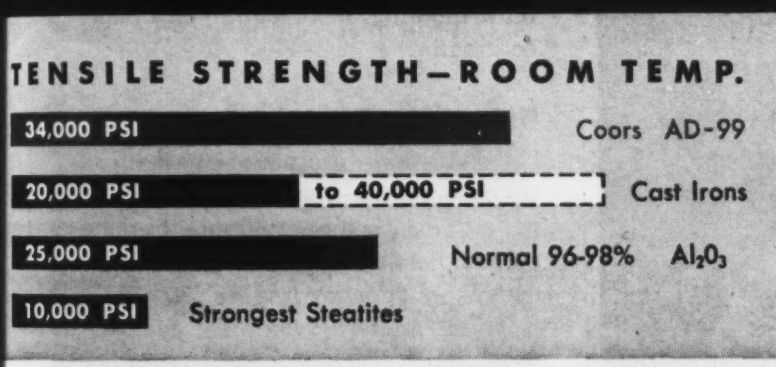
The authors note that care should be taken when using types 201 and 202 at high temperatures, as intergranular attack usually occurs in these alloys at temperatures over 1200 F. This attack is probably due to the high carbon content of these steels (0.15%).

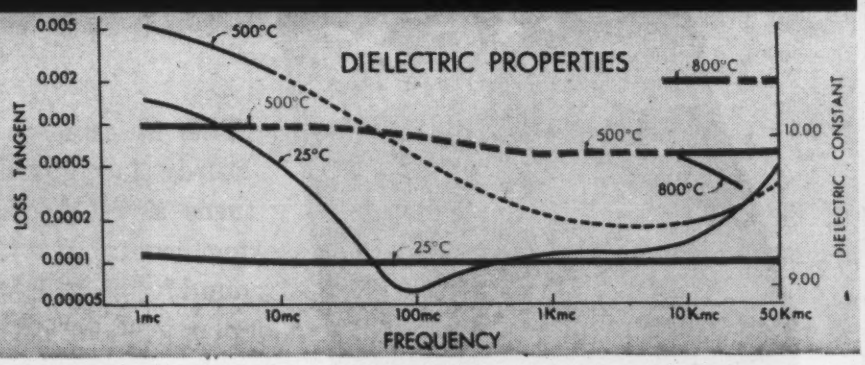
Neither the austenitic stainless steels nor the manganese-containing stainless steels are resistant to attack by sea water. This was confirmed by testing specimens made

For more information, circle No. 498 ➤

NEW AD-99 ALUMINA CERAMIC







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Coors new AD-99 ceramic is non-porous 99.0% Al_2O_3 with the amazing tensile strength of 34,000 psi — as strong as cast iron. It has 30% greater strength than the best commercial high aluminas of 96% to 98% Al_2O_3. It is particularly superior to any ordinary metals in strength at high temperatures —retaining 75% of its tensile strength or 20,000 psi at 2000°F (1100°C).

Coors AD-99 is a superior dielectric material. At modern micro-wave frequencies, loss tangents are lower than those of plastics and all but one or two special ceramic materials—as reported by the Laboratory for Insulation Research, Massachusetts Institute of Technology. At room temperature, the loss tangent is 0.00006 ±0.00002 at 100 mc, less than 0.0001 at 300 mc, and 0.00052 at 50 Kmc.

These properties, combined with the excellent hardness and wear resistance of the alumina family, make this the most superior ceramic now available for commercial use. In addition, Coors AD-99 has complete, unequaled homogeneity made possible only through the use of the Coors isostatic process.*

Originally developed in Coors own laboratory especially for radome work, Coors AD-99 is now available on a commercial production basis for critical electronic and mechanical applications. We can make test parts for your developmental work at nominal costs. Production quantities can be supplied at prices only slightly higher than ordinary alumina ceramics.

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This unusual laboratory—actually a plant—creates nothing commercial, makes nothing for actual sale. Reports on its labors are given freely to GREX customers and prospective users.

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This amazingly sturdy face-guard turns aside the jarring crunch of a 200-pound fullback. It's made of plastic—new GREX high density polyethylene.

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This versatile plastic means better products for you.

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of type 302 and 202 in flowing sea water for 191 days. At the end of the test both specimens were perforated and corroded.

Submitted in partial fulfillment for the degree of MS in Chemical Engineering, Graduate School, Newark College of Engineering.

Plastics Sheet Used in Rockets, Missiles

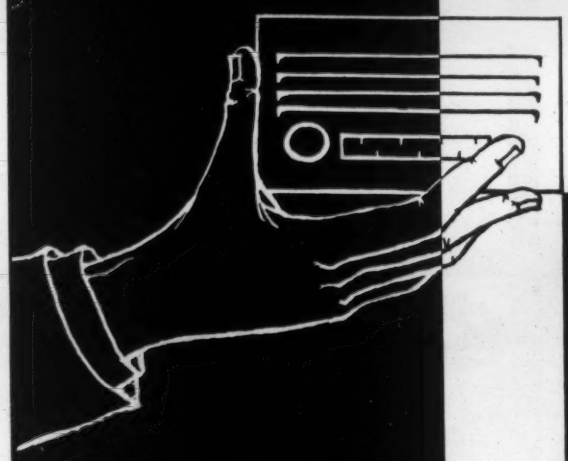
A new silica fiber-reinforced plastics sheet material has been developed by H. I. Thompson Fiber Glass Co., 1733 Cordova St., Los Angeles 7, Calif., for "one shot" rocket and missile applications. According to the producer, the plastics sheet should be particularly useful as liners for rocket engines, and as nozzles and nose cones for intercontinental ballistic missiles. The plastics sheet, designated Astrolite, is made of "pure vitreous silica

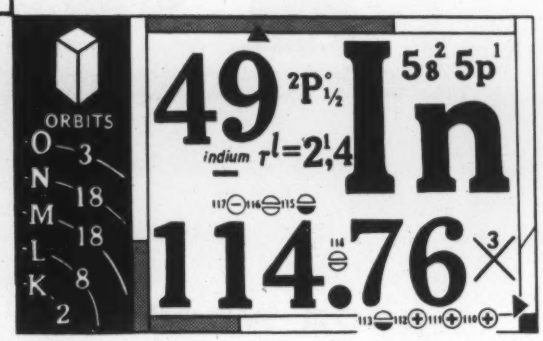
142 sec *are required for a hot flame (4600 F) to burn through a sheet of Astrolite silica-reinforced plastic.*

42 sec *are required for the same hot flame to burn through an alloy steel plate of the same size and thickness.*

49th

LISTEN TO THE ELEMENT





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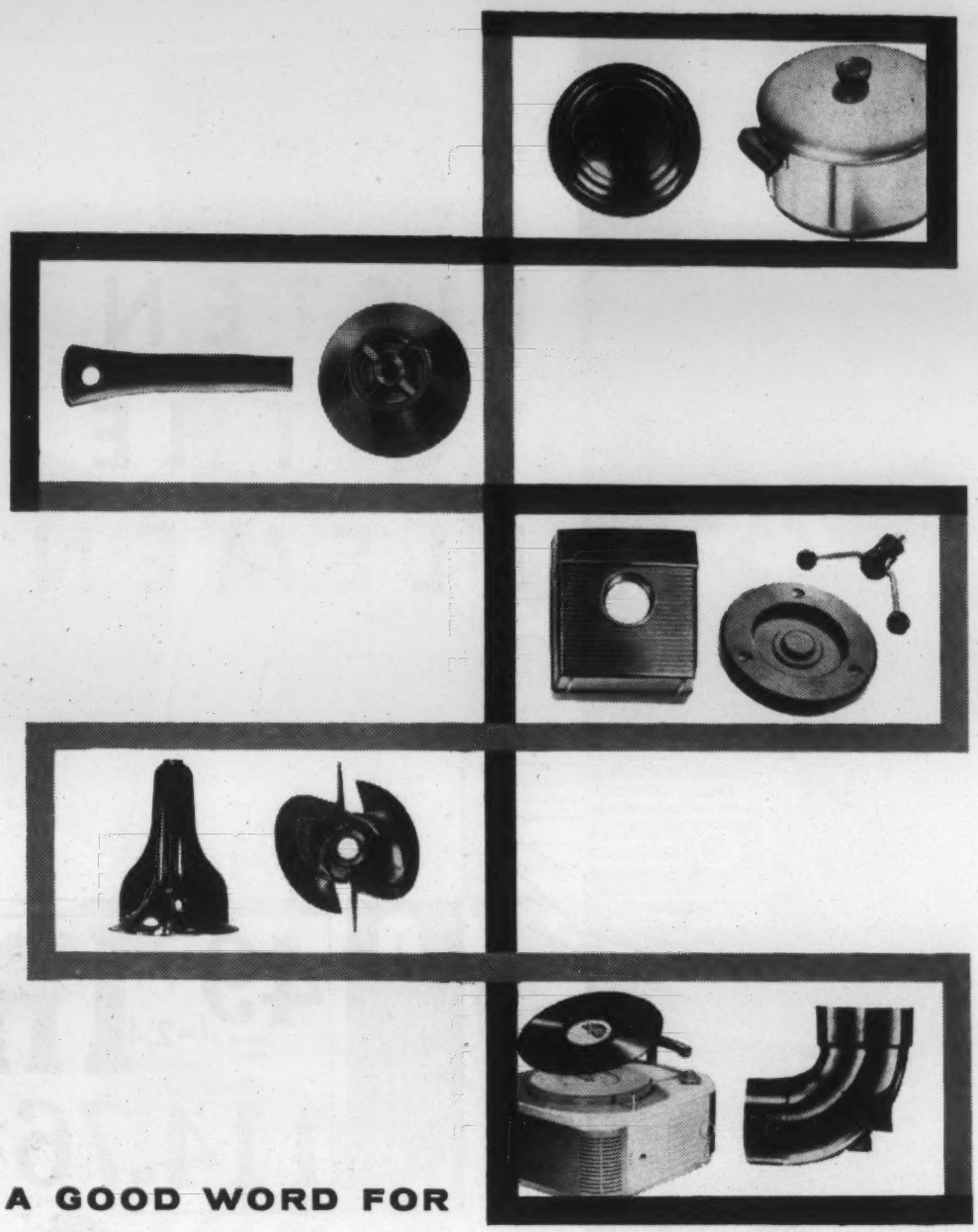

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Serving the plastics industry in the manufacture of high grade phenolic molding compounds, industrial resins and coating resins.

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Sheboygan, Wisconsin

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PROPERTIES OF ASTROLITE

Tensile Strength, psi	8000
Flexural Strength, psi	20,000
Compressive Strength, psi	23,000
Water Absorption, %	1.5
Barcol Hardness	50
Density, lb/cu ft	100

fibers called Refrasil and a high temperature phenolic resin."

Slow burn-through

Slow "burn-through" time seems to be the chief property of the plastics sheet. At a recent demonstration a hot flame (4600 F) took 142 sec to burn through the sheet; the same flame burned through an alloy steel plate of the same size and thickness in only 42 sec.

Although graphite and carbon exceed Astrolite in burn-through times, these two materials are said to be so limited by their brittleness and thermal conductivity that they do not furnish any protection to critical parts behind them. Astrolite, on the other hand, is said to have excellent insulating properties.

The producer says Astrolite can be machined with techniques similar to those used for fiberglass laminates; in general, carbide or diamond tipped tools are recommended for production purposes.

The plastics sheet material is available in production lot quantities in both pre-impregnated fabrics and fabricated parts.

Metallized Paper

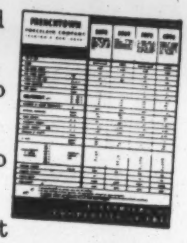
Aluminum metallized paper, said to be ideal for can and bottle labels and carton overwraps, is currently being field tested by Shellmar-Betner Flexible Packaging Div., Continental Can Co., 100 East 42nd St., New York 17.

Shellmar-Betner's new paper products is metallized by processing it in roll form in a vacuum chamber where pure aluminum is deposited upon it. Indications show that the metallized paper,

take a good look at engineered ceramics

When you plan the development of a new product, or seek ways to further improve existing ones, take a good look at *engineered* ceramics in your planning. Our ceramic engineers have developed many new formulae and fabricating methods which greatly enlarge the usefulness of these amazing materials. Whether your problem involves critical or exacting electrical and mechanical properties, chances are *Frenchtown Engineered* Ceramics will provide a better answer. Check these advantages:

- MECHANICAL STRENGTH
  Compressive strength up to 187,000 psi.
- ABRASION RESISTANCE
  Demonstrated by use for sand blast nozzles.
- HEAT RESISTANCE
  Softening temperatures up to 1971° C.
- THERMAL CONDUCTIVITY
  Coefficient (c.g.s. units) up to 0.0180.
- THERMAL EXPANSION
  as low as 2% cumulative at 700° C.



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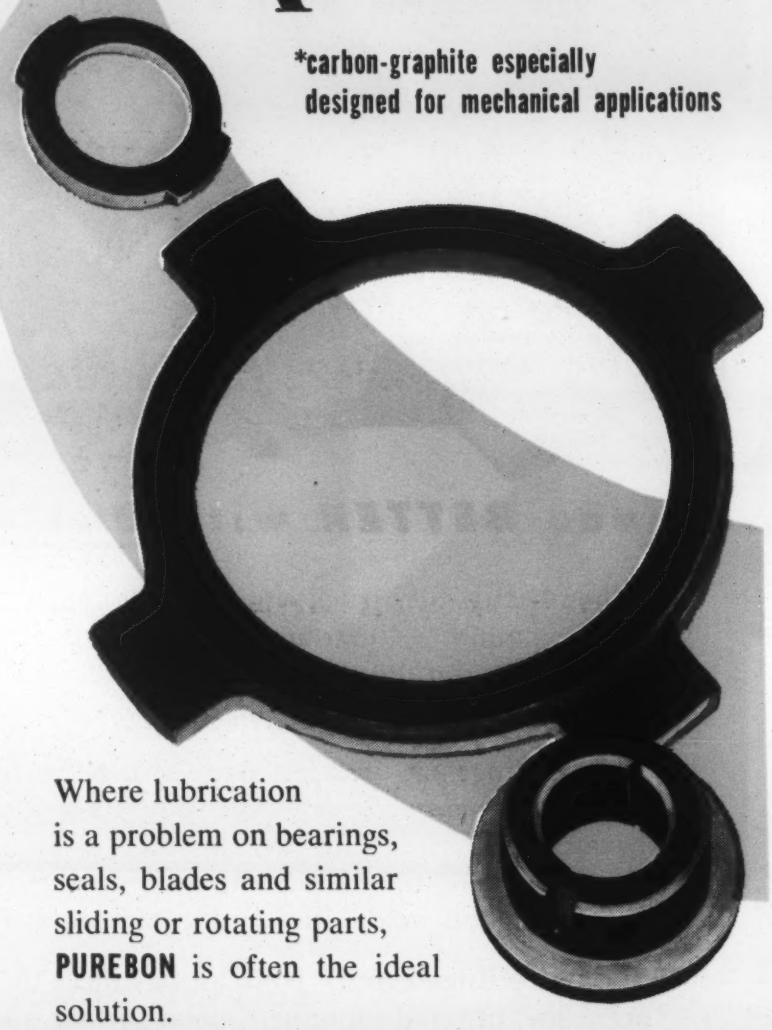

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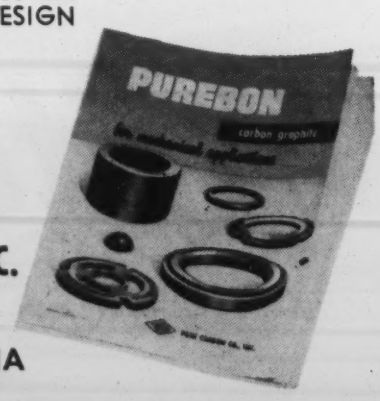

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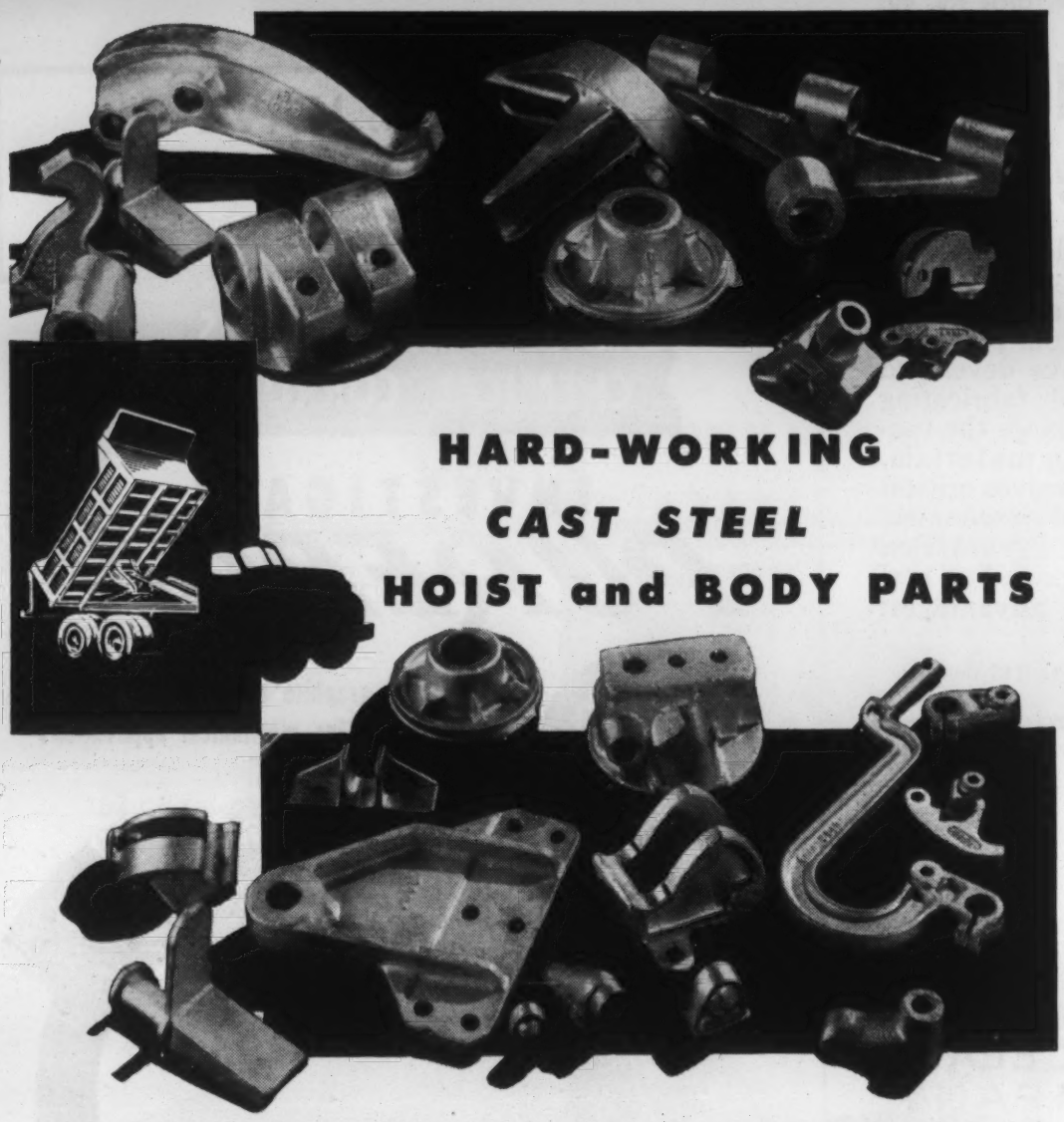

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almost identical to aluminum foil laminations in appearance, will be lower in cost than foil. According to the producer, the paper lends itself well to printing.

Method for Fastening Honeycomb Structures

How to effectively fasten honeycomb structures to aircraft has been a problem to designers ever since the construction was first introduced. Conventional fasteners such as through bolts, screws and rivets usually cause local crushing of the panel when highly concentrated loads are placed upon it.

Designers and fastener manufacturers alike agree that the most promising and effective answer to the honeycomb fastening problem is a lightweight, low cost, and versatile means of reinforcing the fastened area. Wood and metal strips between the skin covers, molded-in plastics blocks, and bonded-in inserts have proved effective, but they are hard to install, rather heavy, and relatively high priced.

Aluminum spacers

A seemingly logical answer to the fastening problem has now been advanced by Raymond J. Schwab, Delron Co., South Gate, Calif. Mr. Schwab says aluminum spacers supply the necessary strength, are relatively easy to install, and are lightweight and inexpensive. He says a number of factors should be considered in selecting a spacer for a particular honeycomb fastening application:

1. Strength-weight ratio at specified operational temperatures.
2. Shear and pull-out strength under expected load reversals or vibrations.
3. Ease of installation in bonded honeycomb panels.
4. Special installation requirements, including a) type of mechanical fastener, b) blind instal-

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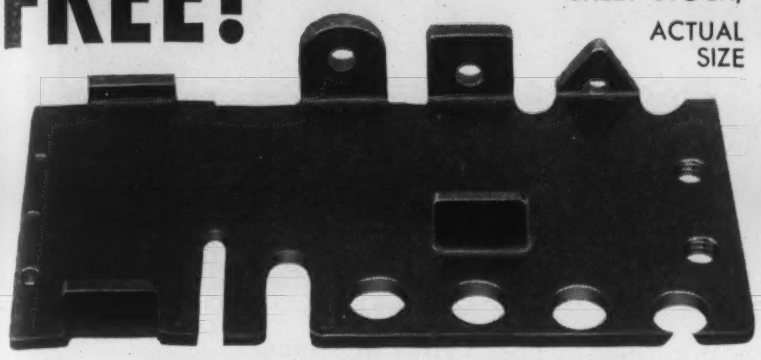

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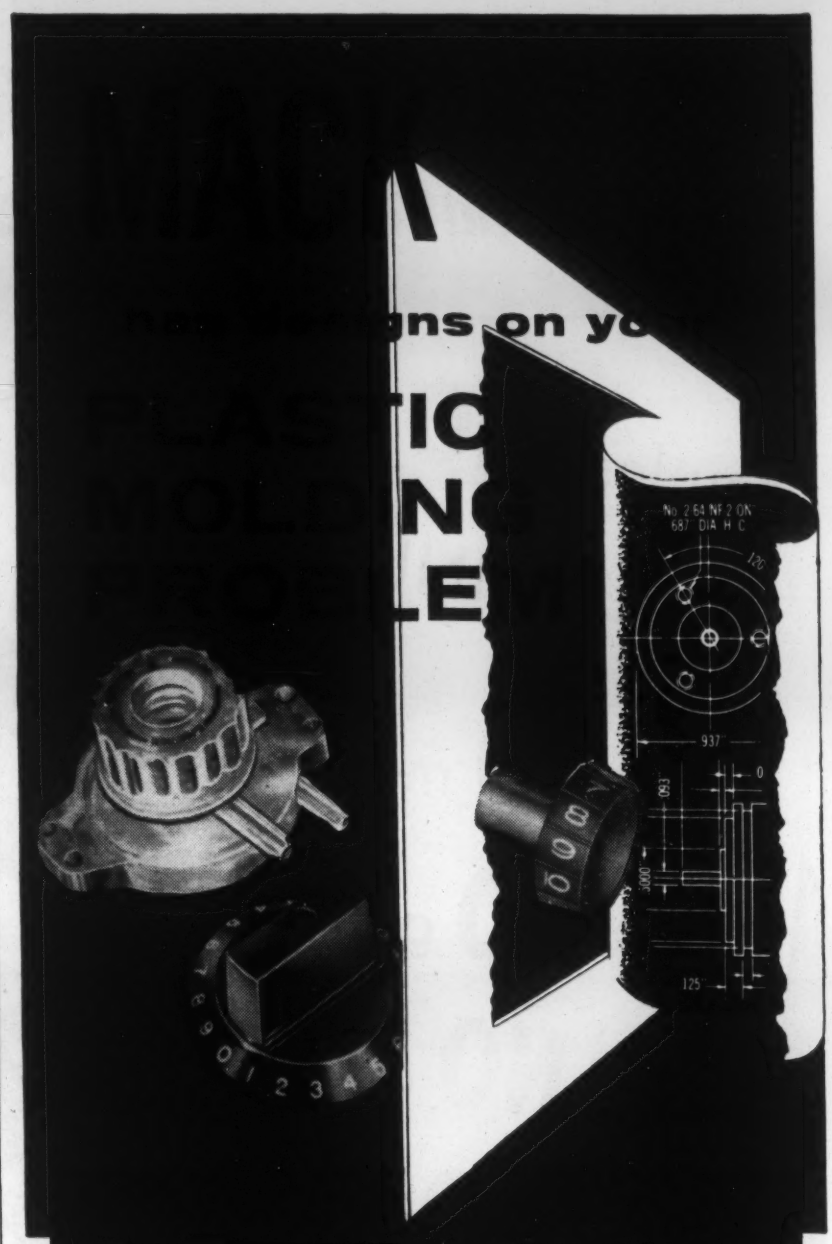

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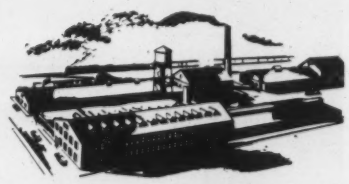

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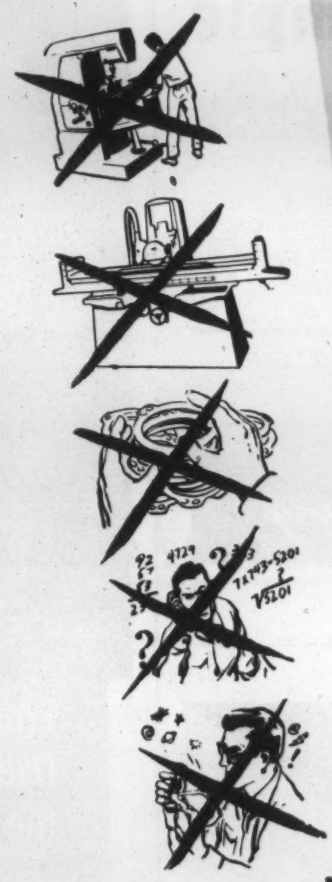

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lation, c) flush installation, and d) ease of replacement in case of damage.

Types of spacers

According to Schwab, many different types of aluminum spacers, manufactured in flat, flush and countersunk heads, are available to meet the above requirements (see Fig 1). A brief description of each follows:

Through-bolt spacers having a smooth inner wall are used where a bolt can be passed through the panel and an assembly fastened to the opposite side and held in place with a nut.

Rivet spacers, similar to through-bolt spacers, but supplied with hole diameters made in accordance with the various standard rivet diameters, are used where permanent rivet installations are preferred.

Internally threaded spacers, furnished with internal threads to fit standard bolt and screw sizes, are used in place of nuts to eliminate the additional bolt and nut length.

Self-locking spacers are a variation of internally threaded spacers but are supplied with a

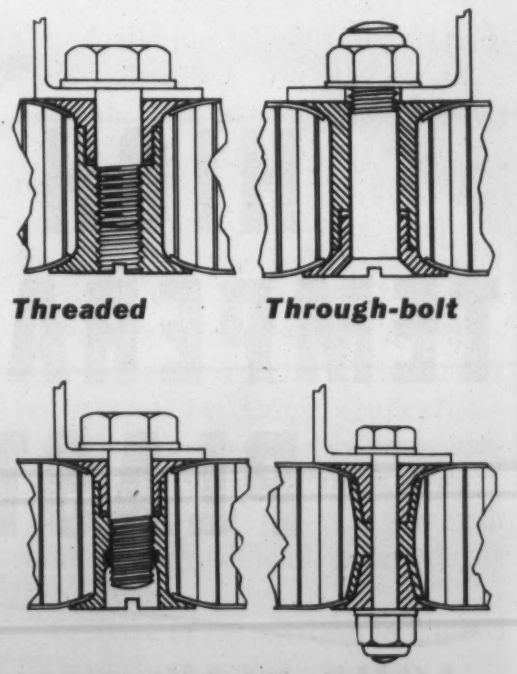
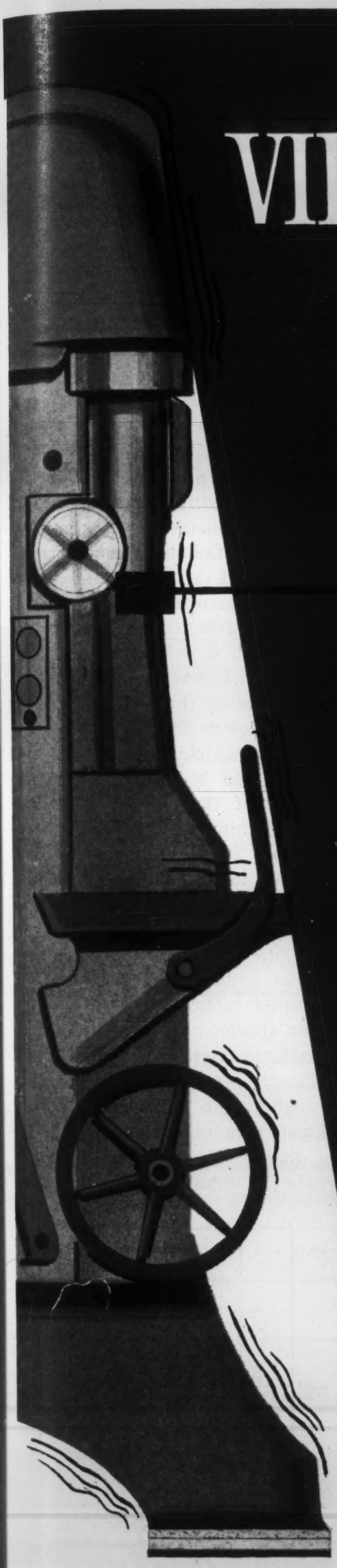


***Fig 1**—Various types of aluminum spacers used to fasten honeycomb structures to aircraft.*

For more information, turn to Reader Service card, circle No. 389



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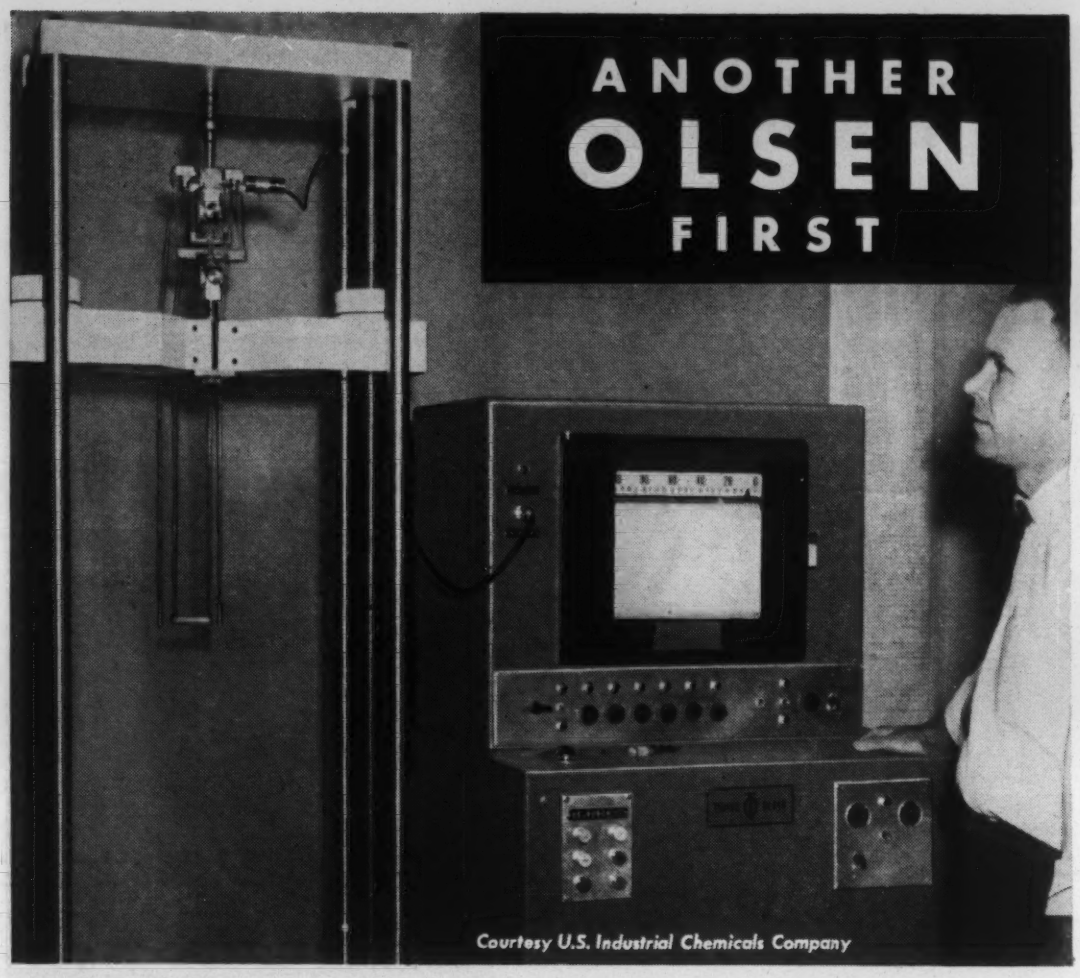

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plastics insert to furnish the self-locking feature.

Structural spacers are similar to the above spacers but are supplied with an internal sleeve. The sleeve is deformed during assembly to grip the cover skin between sleeve and spacer head, providing additional strength under severe vibration.

How spacers perform

Load carrying properties most generally considered in standard honeycomb fastening applications are pull-out strength and compression, according to Schwab. Pull-out strength is maximum load under which an insert can be exposed before it actually pulls away from or through the panel; compression is the amount of deformation which the insert undergoes during loading. A typical example of the pull-out strength of an aluminum structural spacer is shown in Fig 2. The spacer was used to help fasten an aluminum honeycomb structure 3/8 in. thick with a top skin thickness of 0.016 in. Mr. Schwab says all failures occurred by crushing of the panel rather than by failure of the spacer.

Installation data

When installing the spacers in honeycomb structures, Mr. Schwab recommends that a hole be drilled through the entire panel, the diameter of the hole

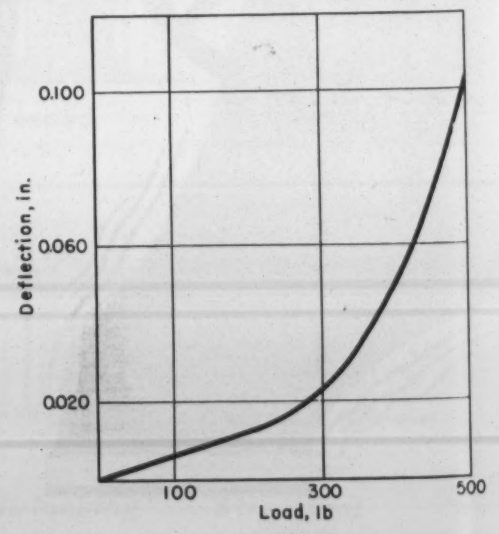

***Fig 2**—Pull-out strength of an aluminum structural spacer used in honeycomb structures.*

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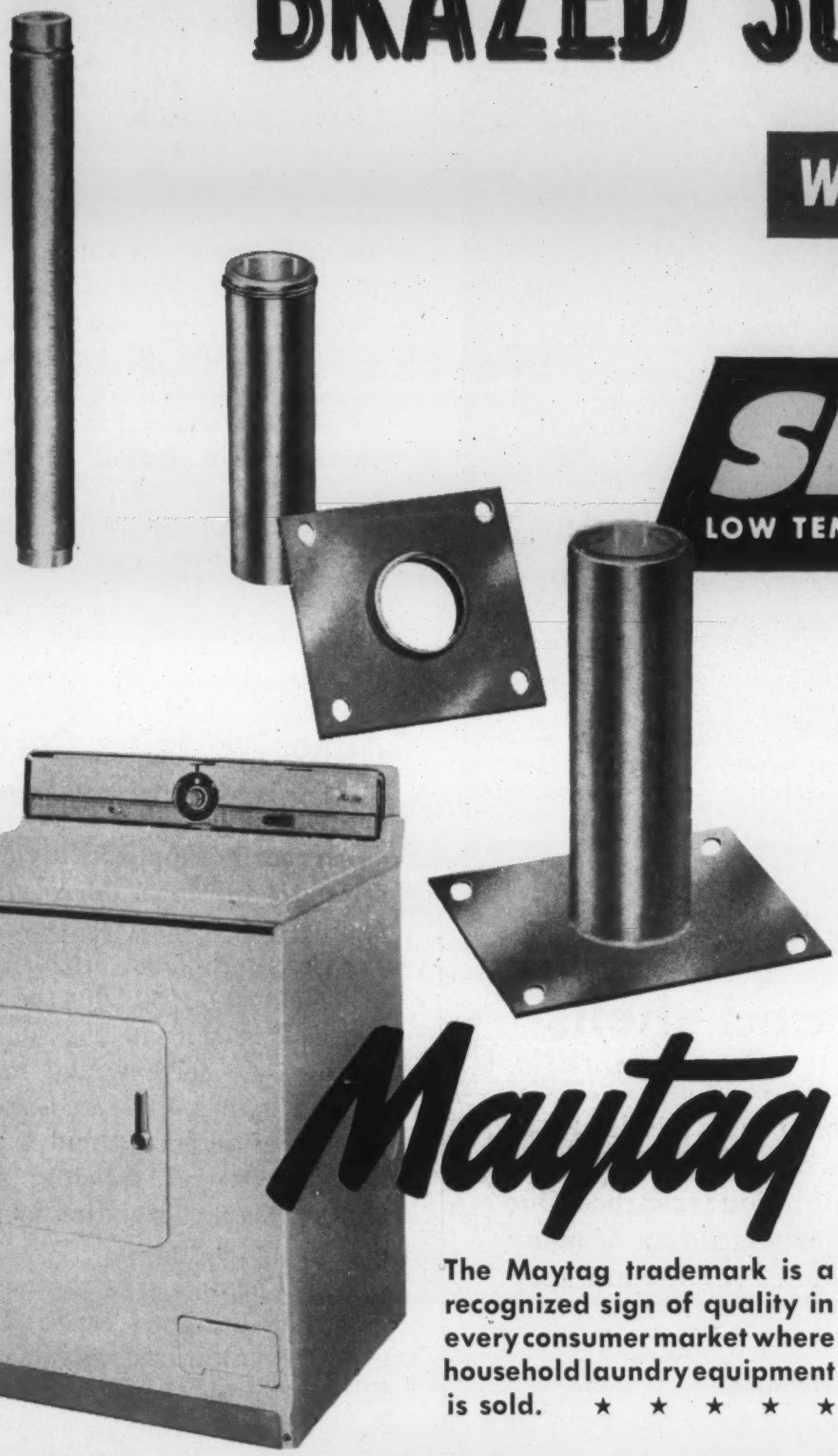

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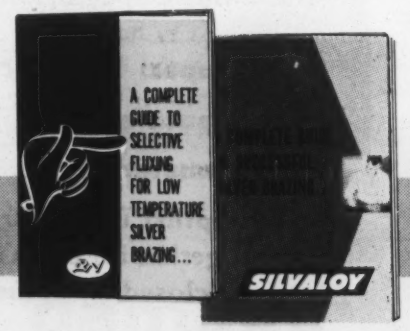

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being the same as the o.d. of the spacer shank. Most of the spacers can be inserted into the honeycomb structure by using a hand arbor, pneumatic or hydraulic press. It is claimed that a trained operator can install up to 200 spacers in an hour. The spacers need not be installed until final attachment of the honeycomb structure to the aircraft, according to Schwab.

Adhesive Joins Cured Silicone Rubber Parts

An easily applied, high bond strength silicone rubber adhesive has been developed by Dow Corning Corp., Midland, Mich. Identified as Silastic S-2200, the material is translucent and nontoxic, contains no solvent, and may be applied with a knife or a spatula. The adhesive should find use in a wide variety of splicing, gasket sealing, blanket mending and duct lining applications.

Dow Corning says the new adhesive is designed especially for bonding vulcanized silicone rubber parts to themselves and to steel, aluminum, brass, copper and zinc. At present, Silastic S-2200 is available in pilot plant quantities at a price comparable to that of conventional silicone rubbers.

How to use

Silastic S-2200 vulcanizes in 5 min at 260 F to create a strong bond between silicone rubber parts. Because the adhesive is solventless, vulcanized silicone rubber parts may be assembled immediately upon application of the adhesive. In order to achieve optimum adhesion of silicone rubber parts to metal, a cure of about 4 hr at 480 F under firm contact pressure is recommended. No special preparation of metal surfaces is required beyond normal cleaning. Good adhesion of silicone rubber parts to metal may be

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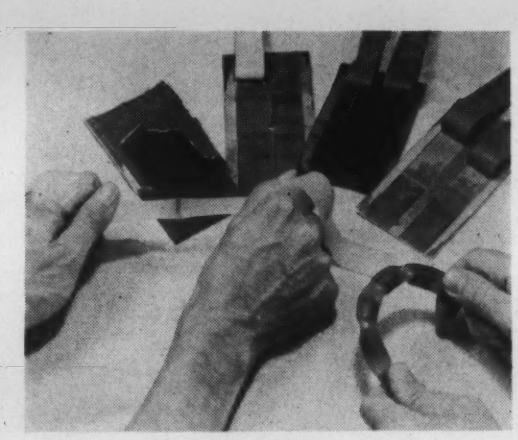

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obtained with shorter cures by using Dow Corning A-4094, a silicone primer which air dries in 30 min.

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Tests indicate that cured films of the adhesive develop pull strengths of 25 lb per in. width and retain both mechanical strength and full resilience at temperatures from –70 to 500 F. The adhesive has a specific gravity of 1.10 and a brittle point of –100 F.

Aluminum Products

Kaiser Aluminum & Chemical Sales, Inc., 919 N. Michigan Ave., Chicago 11, has introduced four new aluminum products — two small sizes of standard alloy pigs and two aluminum foil-to-paper laminations.

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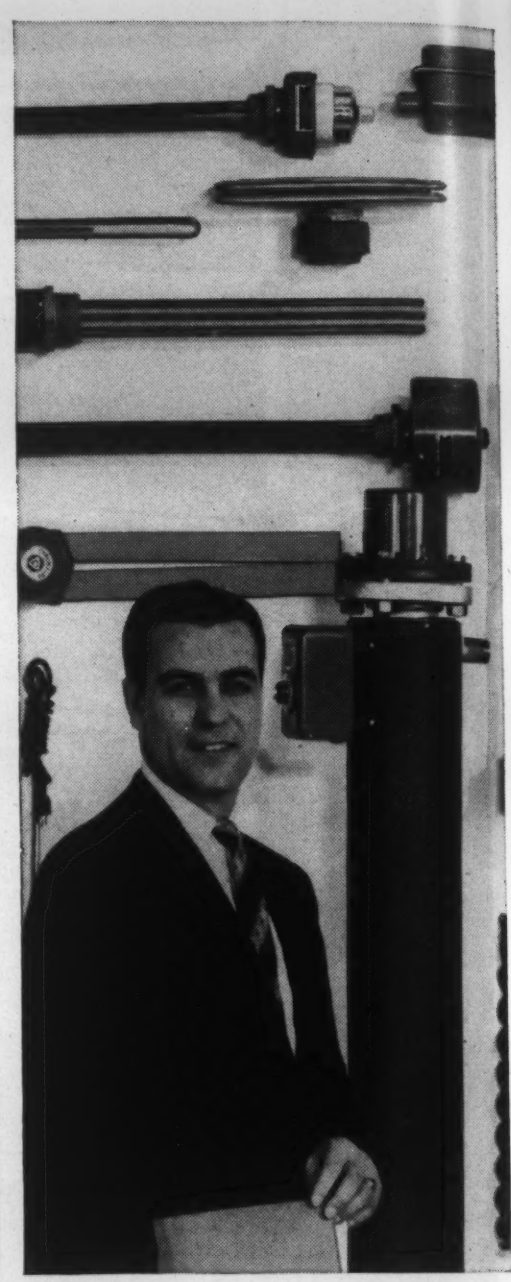

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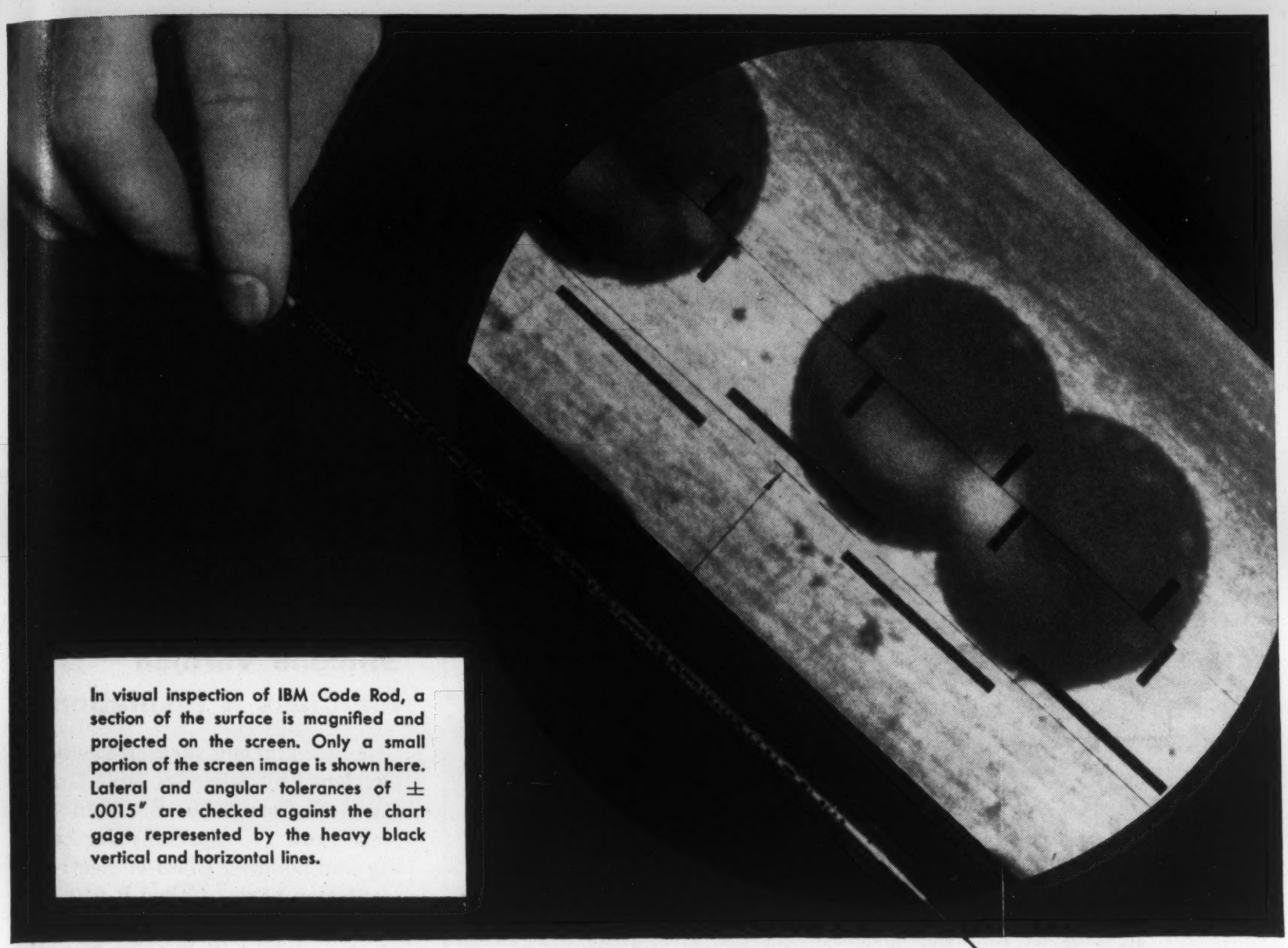

In visual inspection of IBM Code Rod, a section of the surface is magnified and projected on the screen. Only a small portion of the screen image is shown here. Lateral and angular tolerances of ± .0015″ are checked against the chart gage represented by the heavy black vertical and horizontal lines.

How would you gage these 1,118 holes?

Here's how IBM did it... and smashed an inspection bottleneck

Here's how International Business Machines Corporation boosted the inspection rate on its new Code Rod from 1 or 2 *per day* to 15-20 *per shift*—keeping pace with production, yet maintaining complete accuracy—with a Kodak Contour Projector, Model 14-2A.

The Code Rod is used with the new 720 High Speed Wire Printer, developed by IBM to overcome the speed limitations of conventional bar type printers. The rod is a stainless steel tube with no less than 1,118 1/32″ holes. The holes are drilled in various combinations at 7 different intervals in 7 straight rows down the 8″ length of the tube. Obviously the inspection problem is of no small proportions.

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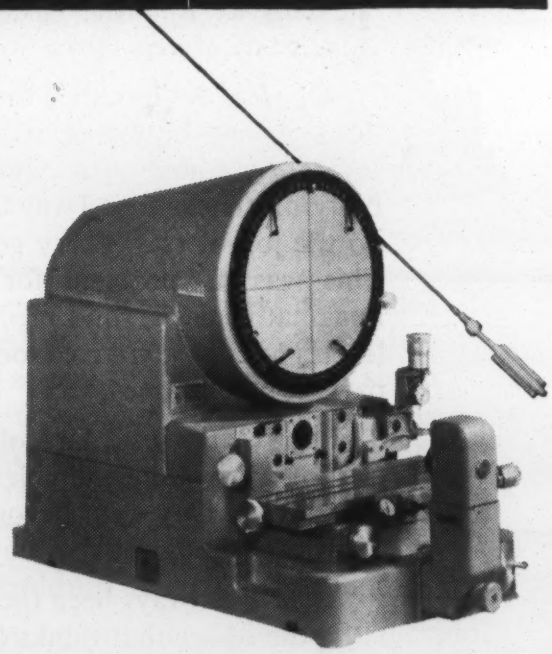
In visual inspection a master Code Rod is placed next to the rod to be inspected. Both surface images are projected on the screen. The operator simply indexes the image along simultaneously, so that he always has a correct rod in view for comparison of the hole grouping. He checks tolerances by a chart gage on the projector screen.

Got an inspection bottleneck at your plant? Optical gaging with a Kodak Contour Projector may well be the answer. The booklet "Kodak Contour Projectors" gives examples of how other firms are profitably using Kodak Contour Projectors, plus full data on the various models we offer. The booklet is available on request from:



Kodak Contour Projector, Model 14-2A, is a versatile precision measuring instrument for production lines or toolroom. It is one of 6 Kodak Contour Projector models available to meet all your optical gaging needs. Operators work in complete comfort, need little training.

Apparatus and Optical Division

EASTMAN KODAK COMPANY, Rochester 4, N. Y.

the KODAK CONTOUR PROJECTOR

Kodak
TRADE MARK

For more information, turn to Reader Service card, circle No. 364

problem solved . . .

when these die-cast twins

replaced this set of gears

It's up to your die caster to get the most from die casting. Here's a case in point.

Original design called for two distinctly different gears. That meant double assembly handling, double parts inventory, added cost. Applying the accuracy and flexibility of die casting, Twin City designed a single gear to do the job of two. Every gear tooth had to be different. This was no problem for die casting but demanded imaginative design and precise tooling at the die-making level. The customer saved tooling money, assembly money, parts control money.

But, that's just part of the story. Twin City Die Casting was willing and able to put itself in the customer's shoes. Twin City went beyond the process of die casting, Twin City thought like a buyer.

That has always been the secret of Twin City's service . . . a die caster that thinks like a customer. Write if you can use that kind of thinking.

...only DIE CASTING can

✔ cut your costs ✔ offer such flexibility
✔ provide such accuracy

Leading Die Casters in the Upper Midwest

TWIN CITY DIE CASTINGS CO.

3351 TALMADGE AVE. S. E. • MINNEAPOLIS 14, MINN. • PHONE MI 6-7528

DIE CASTING RESEARCH FOUNDATION PARTICIPANT

For more information, turn to Reader Service card, circle No. 379

the regular 50-lb size because of equipment limitations.

Foil-paper laminates

The aluminum foil laminations consist of aluminum foil 0.00025 to 0.005 in. thick laminated to tissues, bonds, special papers and paper board. The laminated foil materials are expected to find use as industrial insulations, labels, can liners, carton materials and advertising displays.

Silicone Varnish for Class H Insulation

A new silicone varnish has been developed by Silicones Div., Union Carbide Corp., 30 E. 42nd St., New York 17, especially for coating and bonding Class H electrical insulation parts. Called R-610, the varnish is claimed to retain 90% of its original dielectric strength after seven days exposure at 530 F.

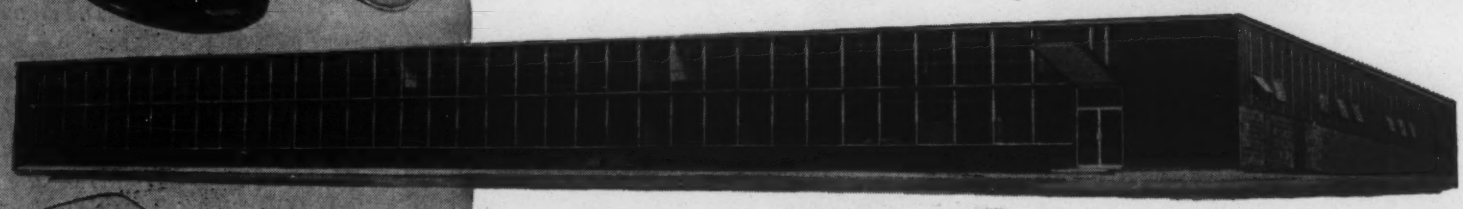
Carbide's silicone varnish can be used to bond mica splittings in many mica tape combinations, including glass backing on one or both sides, and glass backing on one side with Mylar film backing on the other. The varnish can also be used to bond glass cloth with mica, asbestos and glass paper for slot liners, wrappers and phase insulation.

Advantages claimed for the varnish are: low viscosity (75 to 175 cp); good penetration and wettability; fast drying time; adaptability to varying production conditions; low water absorption; and low weight loss upon curing and aging.

Ceramic Magnets Aid D.C. Motor Operation

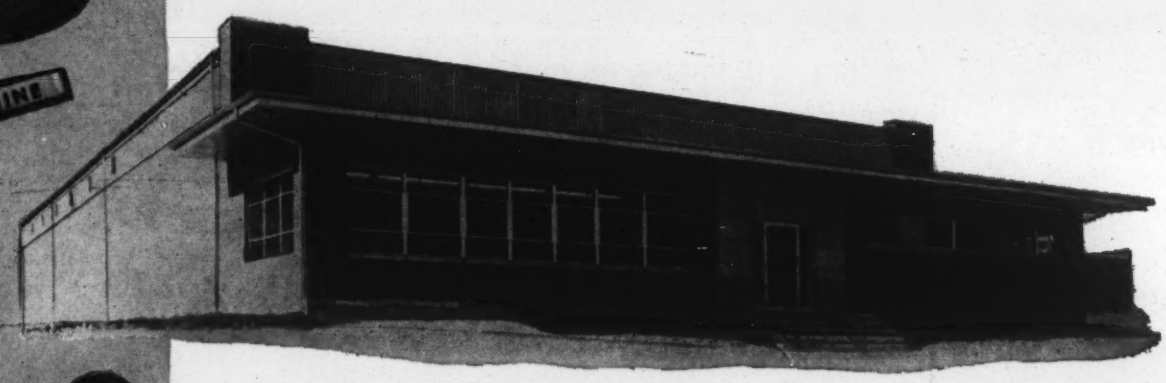
Ceramic permanent magnets seem to be better to use in d.c. motors than conventional copper wound electromagnets, according to engineers at Indiana Steel

INJECTION MOLDING BY CONSOLIDATED



Scranton, Pennsylvania:

The caption takes on added meaning with the opening of our fine new plant, exclusively devoted to injection molding. Located in Lackawanna Valley's Industrial Park, it contains 80,000 square feet of space on one floor and houses 23 injection presses plus unexcelled spray painting, metallizing, and other decorating and finishing facilities. There will be no better injection plant in the East—and no more experienced or knowledgeable production staff.



Binghamton, New York:

New York State manufacturers now enjoy the added convenience of this new addition to our injection molding facilities. Twenty thousand square feet of floor space, seven modern injection presses, new dimensions in decorating and finishing—all these and a sound organization, too, are right on the spot to serve you better.

Whatever your injection molding need, Consolidated has the wherewithal to serve you to your complete satisfaction. Two new plants in operation have equipped us better than ever before to handle any injection molding job. Why don't you see for yourself what our expansion—backed by long experience—can mean to you?

"Your Blueprint in Plastics Since 1874"

At Consolidated, Everything is Modern Except Our Old-Fashioned Pride in Craftsmanship

CONSOLIDATED MOLDED PRODUCTS CORPORATION

Scranton, Pa. and Binghamton, N.Y.

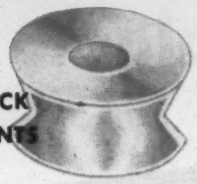
For more information, turn to Reader Service card, circle No. 471

ElastaCAST®

NEW STRUCTURAL MATERIAL

Stronger than Most Metals!

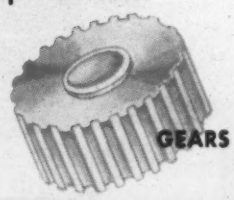
* Licensed under U. S. Pat. 2,764,585



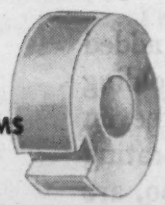
SHOCK MOUNTS

Precision cast shapes to your specifications, this new extraordinary structural material offers unusual mechanical properties making it a much desired choice over metal, nylon and other non-metallics for many applications.

ElastaCAST*, a urethane rubber, utilizes inexpensive tooling to produce component parts at a **new low in unit costs.** Here are five of ElastaCAST's innumerable superior property advantages which make it a must in your requirements for progressive design and greater functional efficiency:



GEARS



CAMS

Extreme High Tensile Strength of 4200 to 7300 psi.

Wide Range of Hardness from 62 to 92 Shore A.

Excellent Abrasion and Tear Resistance.

Good Rebound Elasticity.

Good Resistance to Solvents and Ozone.

PUMP VANES

For complete details on this versatile material, write for the ElastaCAST Engineering Notebook. A competent staff of engineers and laboratory technicians await your product research and development problems.

ACUSHNET PROCESS COMPANY

NEW BEDFORD, MASSACHUSETTS

ElastaCAST DIVISION

Address all communications to **750** Belleville Ave., New Bedford, Mass.

For more information, turn to Reader Service card, circle No. 445

What's new IN MATERIALS

Products Co., Valparaiso, Ind. The engineers say Indox I and Indox V ceramic permanent magnets introduced earlier this year (see MATERIALS & METHODS, June '57, p 192) offer the following advantages over copper wound electromagnets:

1. Lower magnet cost.
2. Cooler operation of the motor.
3. Higher operating efficiency.
4. Lower fabricating cost.
5. Simplified motor design.

It is claimed that the ceramic magnets do not become demagnetized when opposed by strong armature fields in d.c. motors. Indox I is especially suited for small d.c. motors whereas Indox V is suited for large motors of 10 hp or more.

Noncritical Iron Alloy for Electrical Switches

An iron - chromium - aluminum alloy has been added to Hoskins Mfg. Co.'s line of nickel-chromium resistance alloys for use in moderately high temperature resistant heating applications, such as small appliances. The company, located at 4445 Lawton Ave., Detroit 8, says the new alloy contains no critical materials and is relatively inexpensive. Designated Alloy 815, it is said to have high volume resistivity (815 ohm-cm), low specific gravity and good resistance to oxidation.

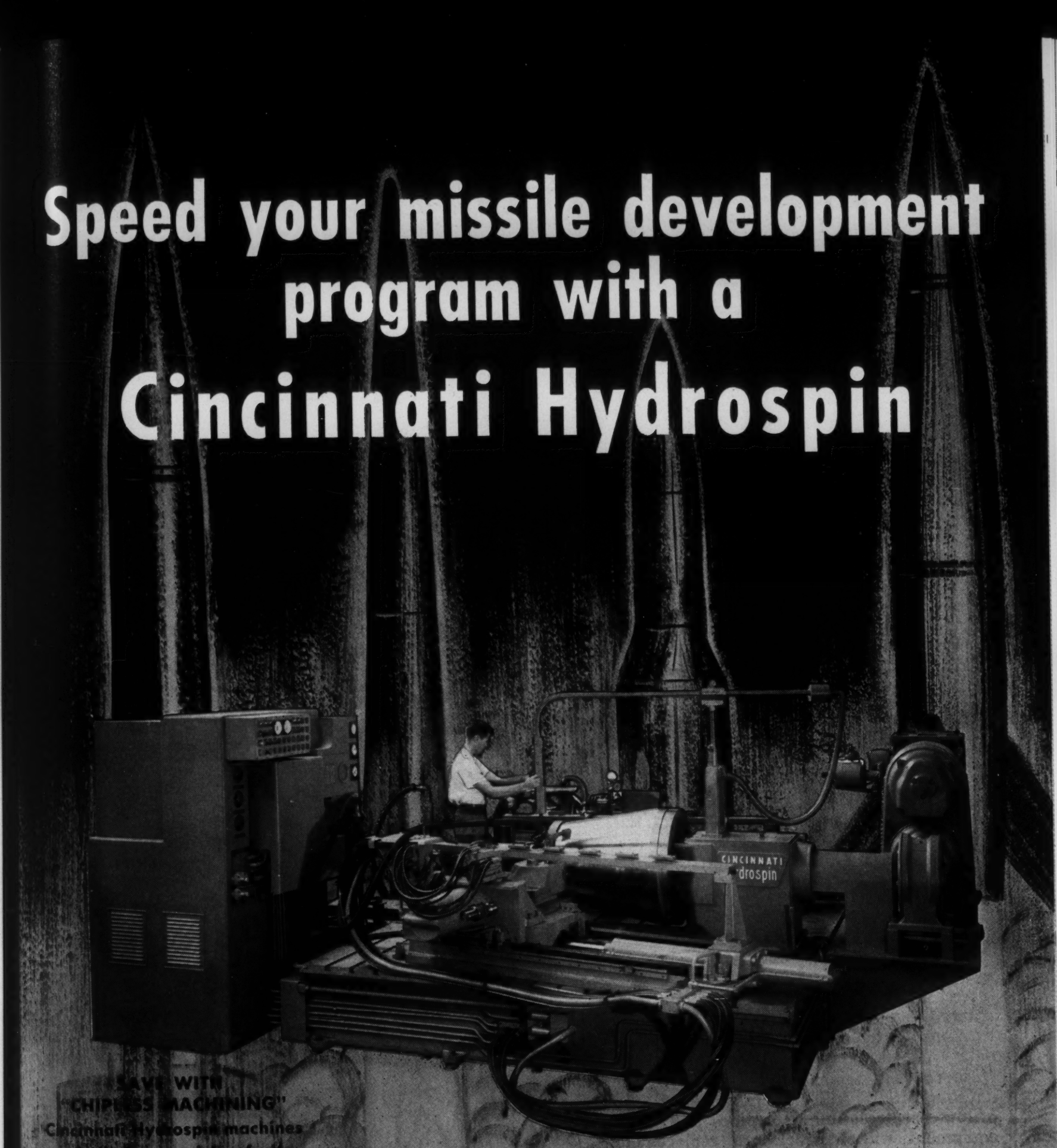
The alloy should be useful for certain "cold" resistor applications such as defroster units, contact switches and rheostats. It should also be useful in industrial heating devices where continuous operating temperatures do not exceed 2150 F.

Copper Electroplates Brighten in a Hurry

Smooth and ductile copper electroplates that can be buffed as easily as gold can be obtained

For more information, circle No. 419 ➤

Speed your missile development program with a Cincinnati Hydrospin



SAVE WITH "CHIPLESS MACHINING"

Cincinnati Hydrospin machines are built in a variety of sizes and styles to meet your missile production requirements.

With a Cincinnati Hydrospin®, you move metal—do not remove it—to produce motor sections and other curvilinear, tubular, conical and hemispherical missile shapes. Tool costs are low. A mandrel, contoured to the desired part shape, is all the tooling required. Part production is fast. Contours and wall thickness of the part can be closely controlled. Greater part strength, hardness, and fatigue resistance result from the severe shear deformation. Get detailed information now. Call in a Process Machinery Division field engineer.

CINCINNATI **Hydrospin**

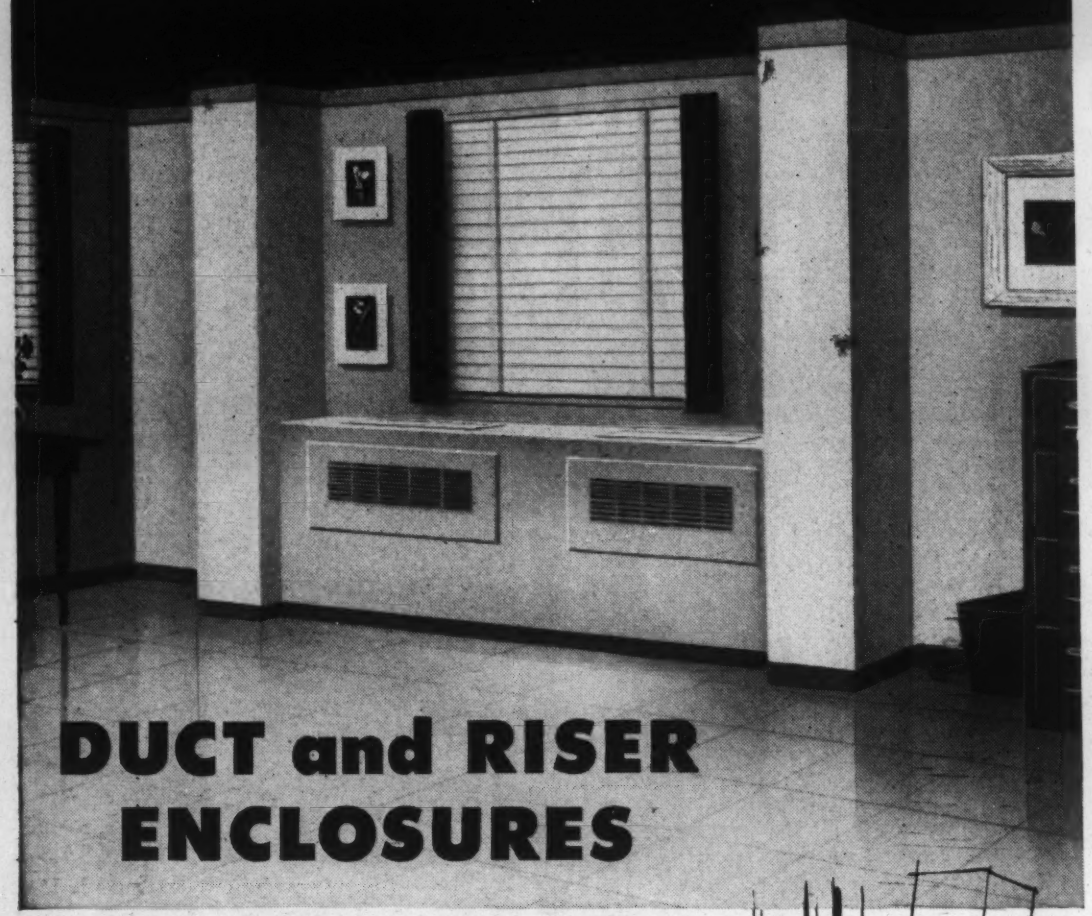
PROCESS MACHINERY DIVISION

THE CINCINNATI MILLING MACHINE CO

CINCINNATI 9, OHIO, U. S. A.

MET-L-WOOD

METAL BONDED TO PLYWOOD



DUCT and RISER ENCLOSURES

. . . faster, cleaner installation

. . . lasting finished beauty

. . . complete accessibility

Installing Met-L-Wood riser enclosures, air ducts, convector covers and paneling benefits everyone connected with the job:

Architects and contractors plan on substantial installation time savings and know that smooth, uniform Met-L-Wood needs only paint to finish after installation.

Building management not only gets a clean, durable installation, fast; but is also assured of low-cost accessibility to pipes and other equipment without enclosure replacement expense.

Met-L-Wood units are pre-formed, ready to install with minimum labor. When finished, Met-L-Wood sections match perfectly with conventional walls and ceilings.

Whether you plan new construction or remodeling, write for literature now and learn all the advantages and economies you gain with Met-L-Wood.

MET-L-WOOD®
CORPORATION

6755 W. 65th Street
Chicago 38, Illinois

For more information, turn to Reader Service card, circle No. 421

What's new IN MATERIALS

with a new acid copper plating process called CuSol. The process, developed by Sel-Rex Corp., Nutley, N. J., consists of two special addition agents that may be added directly to existing copper sulfate or copper fluoroborate baths or may be used to make up original baths. Among advantages claimed for the copper plating process are:

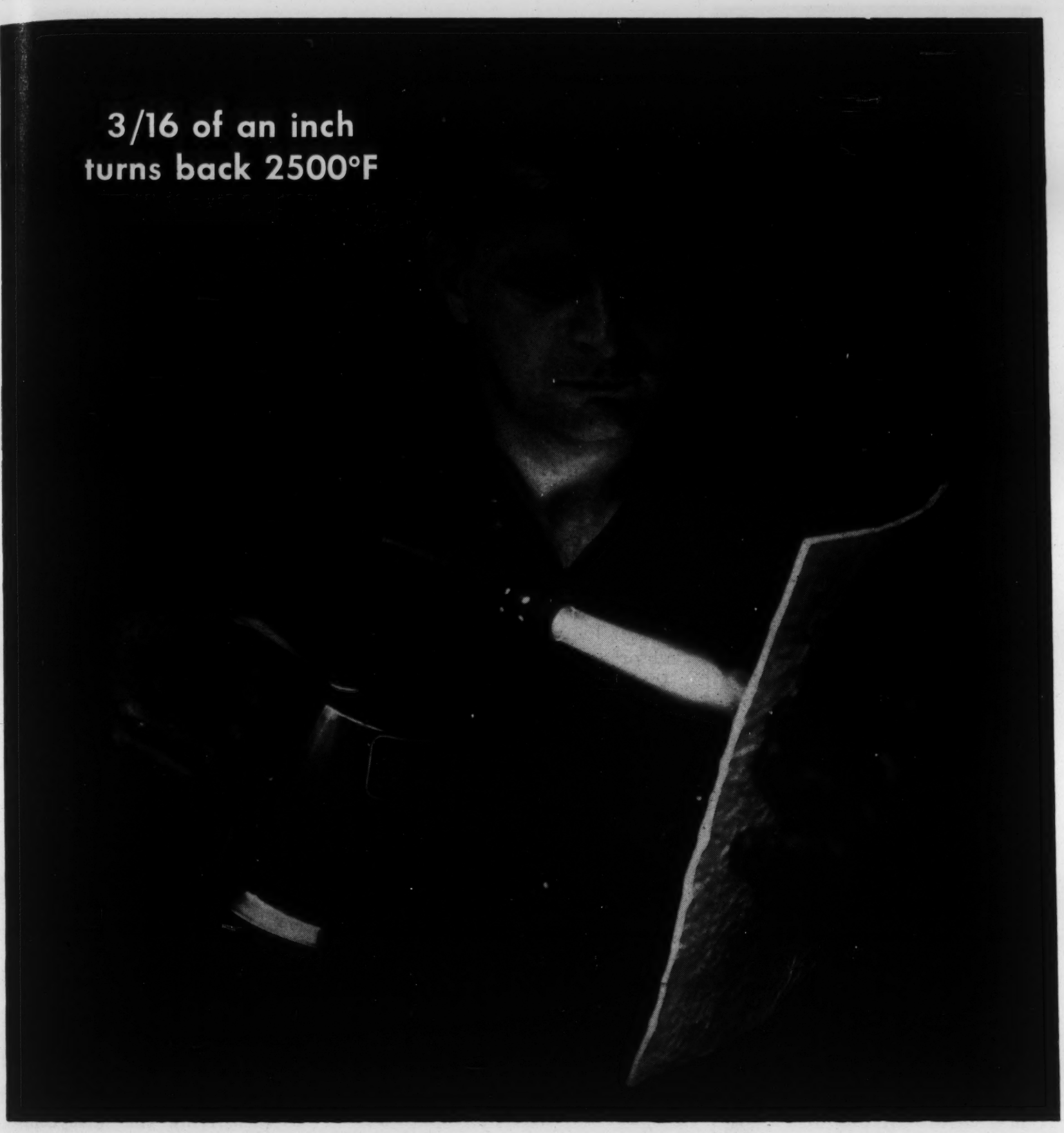
1. It has good throwing power, affording evenly distributed deposits even in blind holes.
2. Bath may be operated over range of current densities from 5 to 280 asf.
3. When used for heavy deposits, it eliminates the need for periodic reverse or "de-plating" methods in order to insure smooth deposits.
4. The bath is particularly useful for printed circuits, since the acid solution does not affect plastics laminates as do cyanide solutions.

Two Silicone Greases Operate at 600 F

Two silicone greases have been developed to lubricate bearings at temperatures from –45 to 600 F. Designated ETR Grease B and ETR Grease D, the lubricants performed satisfactorily for 162 hr at 600 F in a test rig operating at 10,000 rpm.

In addition to high temperature resistance, the greases have low evaporation rates, good water resistance and good mechanical stability. The two greases were developed by Shell Oil Co., 50 W. 50th St., New York 20, to meet the high speed and high temperature lubrication requirements of supersonic aircraft and missiles.

SOURCES of most engineering materials can be found in M/DE's "Materials Selector" reference issue, published last September. Properties of all materials are also given.

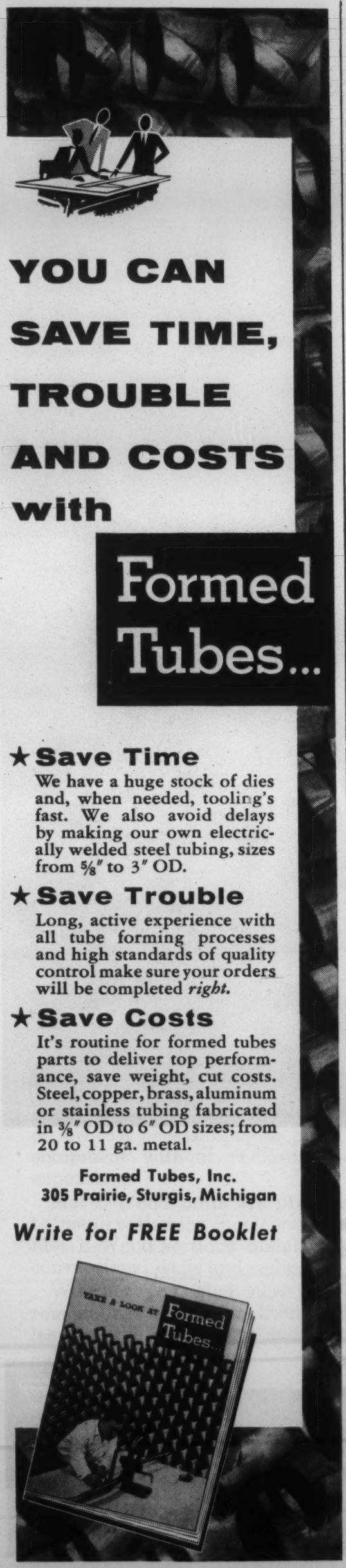


MICRO-QUARTZ... this new, lightweight insulation laughs at high temperatures—even beyond 2000°F. It's especially useful where space and weight requirements are stringent, because it weighs only 3 lbs./cu. ft. And Micro-Quartz takes punishment in stride: keeps its fibrous form at high-temperatures—stands up well under vibration. Other facts you should know: It's boron-free, has low heat capacity and high thermal diffusivity, contains no organic binder. Micro-Quartz, in bulk or felt, may be the answer to your most perplexing high-temperature insulation problem. For data write on your letterhead to: L·O·F Glass Fibers Company, Dept. 37-38, Toledo 1, O.

L·O·F GLASS FIBERS

L·O·F GLASS FIBERS COMPANY • TOLEDO 1, OHIO

For more information, turn to Reader Service card, circle No. 429



YOU CAN SAVE TIME, TROUBLE AND COSTS with

Formed Tubes...

★ **Save Time**

We have a huge stock of dies and, when needed, tooling's fast. We also avoid delays by making our own electrically welded steel tubing, sizes from 5/8" to 3" OD.

★ **Save Trouble**

Long, active experience with all tube forming processes and high standards of quality control make sure your orders will be completed *right.*

★ **Save Costs**

It's routine for formed tubes parts to deliver top performance, save weight, cut costs. Steel, copper, brass, aluminum or stainless tubing fabricated in 3/8" OD to 6" OD sizes; from 20 to 11 ga. metal.

Formed Tubes, Inc.
305 Prairie, Sturgis, Michigan

Write for FREE Booklet

For more information, circle No. 363

MATERIALS AT WORK

Die castings—cont'd from p 12

casting, a slower casting cycle would have been necessary and investigation proved that mechanical piercing was actually more economical. All 16 openings are punched in a single operation. The entire cleaner unit, including a 1-hp motor, weighs only 11½ lb.

According to Interstate Precision Products Corp., the following considerations led to the selection of aluminum die castings: 1) the units had to have a pleasing design as well as accommodate the components of the cleaning system; 2) they had to be strong enough to outlast a 10-year guarantee; 3) they had to be light in weight; and 4) servicing had to be easy.

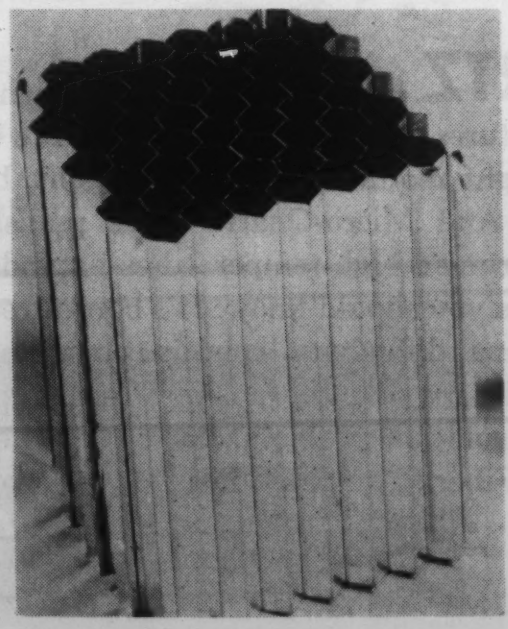
Honeycomb Absorbs Shock

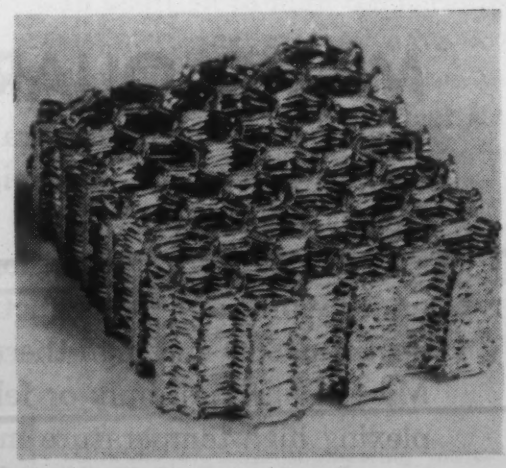
Aluminum honeycomb cores densified with foamed plastics make the best possible shock absorbers, according to Hexcel Products, Inc. The reason for this is that the collapse upon impact of the aluminum honeycomb takes the form of accordion folds. These folds in the cell sides (shown in the accompanying photo) start at one face and occur progressively, causing the core to collapse at a constant rate during impact.

Most padding materials deform in a non-linear fashion; the more deformation, the higher the resistance to further deformation. An "ideal" shock absorber provides a constant resistance force during its total deformation. The constant resistance to deformation demonstrated by aluminum honeycombs comes closest to duplicating the characteristics of an ideal shock absorber.

This is shown in the accompanying stress-strain curve for a typical honeycomb sample. The high initial peak represents the inherent strength of the core before failure has started; it is followed by a flat section, proportional in duration to the depth of the core, during which the accordion action takes place. The final high plateau occurs after the core material has been completely crushed and is effectively a solid block of aluminum. The initial high peak is undesirable because it may cause a momentary force beyond the design limits; in order to offset this, the core is deliberately deformed slightly before installation in most applications.

By densifying the honeycomb





Accordion-type collapse *of aluminum honeycomb core accounts for its excellent impact absorbing characteristics.*

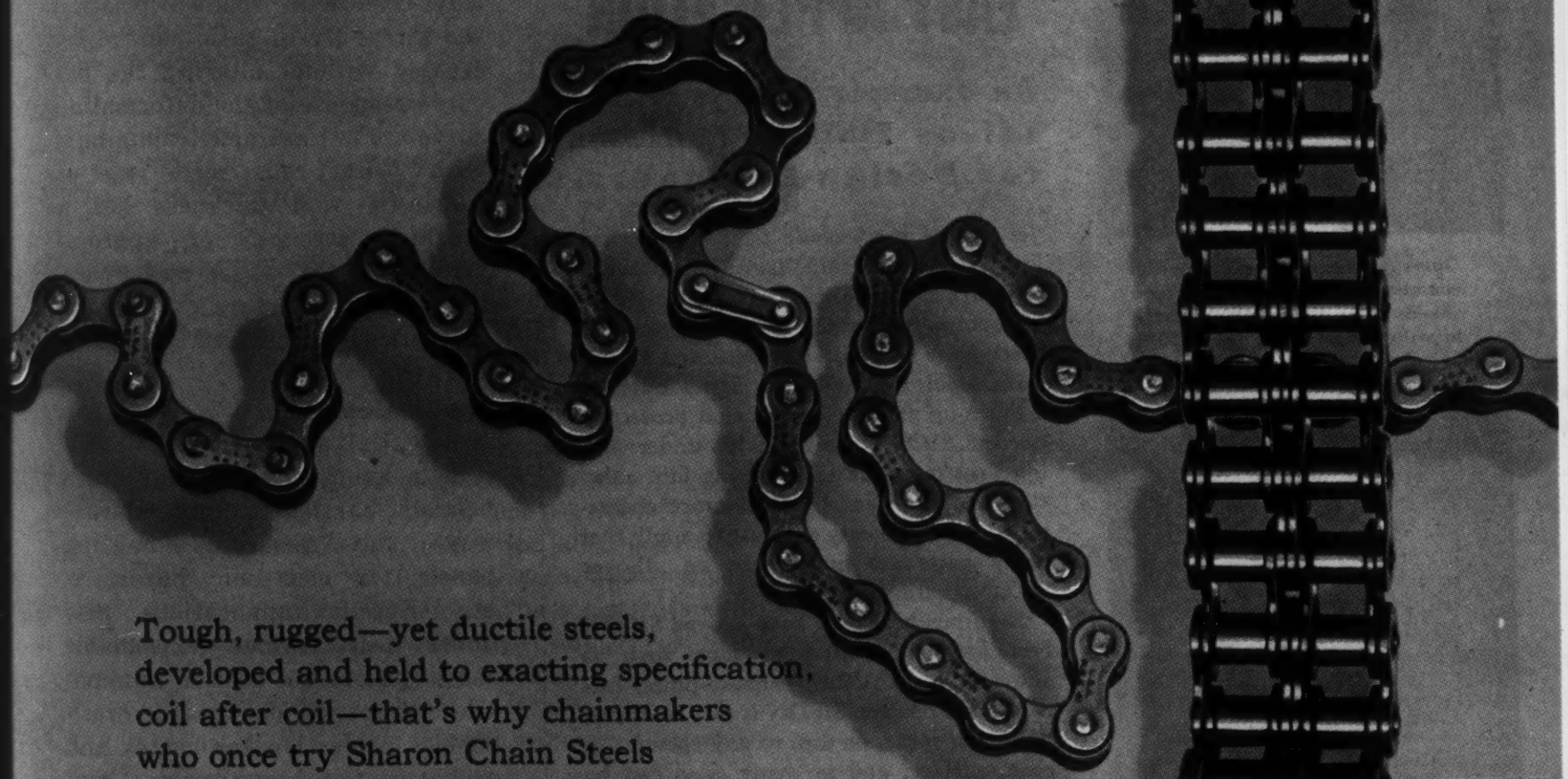
For more information, circle No. 500

Better Chains...

BEGIN WITH

SHARON QUALITY

CHAIN STEELS



Tough, rugged—yet ductile steels, developed and held to exacting specification, coil after coil—that's why chainmakers who once try Sharon Chain Steels become regular buyers.

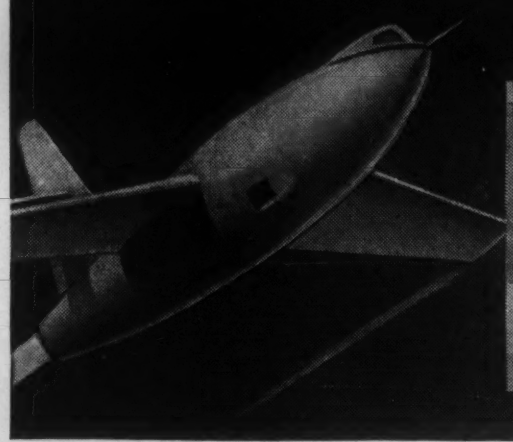
If you are in the business of making chain, why not talk to Sharon metallurgists and take advantage of the first-hand knowledge of chain steels that comes from years of developing special alloys for the chain industry.

SHARONSTEEL

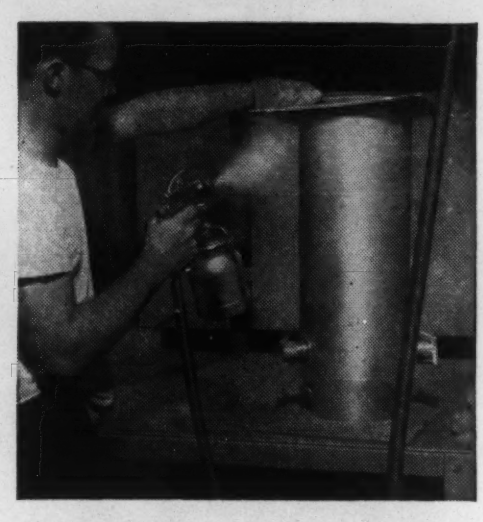
SHARON STEEL CORP.

SHARON, PENNSYLVANIA

PROTECTING JET ENGINE PARTS with Sicon Silicone Coating



Allison J-35 A-35 assembly of Solar-built parts. SICON is used as a protective coating on combustion chambers, aft-frames, other jet engine parts, and afterburners.



Operator masks end of combustion chamber with simple cardboard shields as he applies SICON finish to resist temperatures up to 800°F.

This J-35 afterburner shroud assembly has been masked at critical hole patterns and threaded attachments before being sprayed with SICON silicone coating.

HEAT RESISTANCE UP TO 800°F. *plus* EASY APPLICATION

An example of how SICON solves Finish Problems for Design Engineers.

Jet engine parts made by Solar Aircraft are fabricated from special aluminized steel to meet conditions of extremely high temperatures. Certain welding operations destroy the aluminized surface, and at such critical points SICON was first adopted as a touch-up finish to renew vital protection needed. SICON proved stable under searing heat tests due to its strong film adhesion and excellent heat resistance characteristics, also so easy and fast to apply that many parts are now given an all-over SICON coating.

Rigorous heat tests have proved SICON best for many other products such as automobile manifolds, exhaust pipes, furnaces, and heaters. SICON is easy to apply, by brush, spray, or dip, to any chemically clean surface; and in many cases can be either air-dried or baked.

Decorative colors for lower temperature needs—whites, beiges, tans, and other shades, all with excellent retention of color and gloss in the 550°F. range, are now available.

Write us about your problem. If a SICON formulation is indicated we will provide a sample based on color and temperature requirements. *Dept. C-1*

MIDLAND Industrial Finishes Co.
EAST WATER ST., WAUKEGAN, ILLINOIS
ENAMELS • SYNTHETICS • LACQUERS • VARNISHES

Sicon

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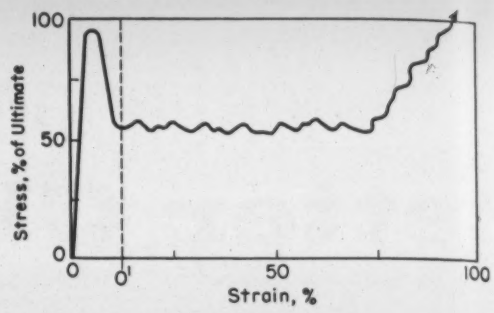


Dynamic measurement *of aluminum honeycomb core collapse shows nearly constant stress with increasing strain after initial strength of core has been overcome. Slightly deforming the core material before impact eliminates initial peak load and displaces ordinate axis to 0'.*

core cells with foamed plastics, the stress-strain ratio can be increased without altering the flat curve response of the deformation curve. For example, aluminum with ⅛-in. cells made up of 0.0015-in. wall thickness has a crushing strength of approximately 350 psi. Filled with foam, the same structure's crushing strength is increased to about 2500 psi.

Applications

Potential applications for aluminum honeycombs include crash helmets, barriers on ground runways and carriers, mounting panels for electronic hardware, etc. Specific applications now under test include expendable shock absorbers behind automobile bumpers; dashboard crash panels; protection for crates and packages for heavy parts; and pallets for emergency air drops.

Special Glass Insulation for Underground Pipe

Without sacrificing strength, a new type of underground insulated pipe conduit is said to be 50% lighter than previously used corrugated galvanized steel, and to be unaffected by moisture or corrosive electrolytic action of the earth. Called Temploc and pro-

NEW FROM DU PONT RESEARCH

Remarkable, resilient **FAIRPRENE**® performs continuously to 500°F; resists fuels, lubricants, solvents and harsh chemicals

PHYSICAL PROPERTIES

	Original	After 72 hrs. in dry air at: 450°F	500°F
Tensile strength	1410	1270	1173
Elongation, Ultimate, %	200	153	153
Durometer, Shore A	75	75	80

Tests were made on new "Fairprene" fluoroelastomer sheet stocks of .043" gauge and 24" width. Tests show excellent maintenance of basic properties to 500°F.

Now, Du Pont research has developed an elastic, resilient material—"Viton" A fluoroelastomer—with remarkable high-temperature and chemical resistance. In tests, "Fairprene"* sheet stocks and coated fabrics of this new material for gasketing and diaphragm show excellent maintenance of basic properties at 500°F. This new "Fairprene" resists acids, alkalies, ozone and weathering. It resists swelling and deterioration in solvents, oils, lubricants and fuels. For more information about these new "Fairprene" sheet stocks and coated fabrics of amazing "Viton" A*, mail the coupon—no obligation.

IMMERSION TESTS

Fluid or Fuel Specification	Temperature level—°F	Volume swell—%
JP-4 Fuel (Kerosene-base jet fuel)	212	1.7
JP-5 Fuel (Kerosene-base jet fuel)	350	5.9
Univis J43 Hydraulic Fluid (Oil type)	500	5.9
Turbo Oil #15 (Diester-type lubricating oil)	500	16.0
ASTM #3 Oil (Petroleum base, low aniline point oil)	500	8.5
ASTM #1 Oil (Petroleum base, high aniline point oil)	500	0.0
OS45 (Silicate ester base hydraulic fluid)	350	6.5
SR6 (High aromatic test fluid)	Room Temp.	3.4
SR10 (High aliphatic test fluid)	Room Temp.	0.0
Benzol (Basic aromatic hydrocarbon solvent)	Room Temp.	19.3

Tests were made on new "Fairprene" fluoroelastomer sheet stock of .043" gauge and 24" width. Information on fluids or fuels not included can be developed by our laboratory on request.

DU PONT INDUSTRIAL COATED FABRICS SHEET STOCKS • CEMENTS

DU PONT
REG. U. S. PAT. OFF.

BETTER THINGS FOR BETTER LIVING . . . *THROUGH CHEMISTRY*

*"*Fairprene" is Du Pont's registered trademark for its coated fabrics, sheet stocks and cements. "Viton" A is Du Pont's registered trademark for one of its synthetic rubbers.*

Mail coupon now for more information about new "Fairprene" with amazing "Viton" A

E. I. du Pont de Nemours & Co. (Inc.)
Fabrics Division, Dept. MD-83, Wilmington 98, Delaware

Please send me more information on this new "Fairprene" with remarkable high temperature and chemical resistance.

Name _____ Position _____

Company _____

Address _____

City _____ State _____

For more information, turn to Reader Service card, circle No. 506

DESIGN HISTORY IS BEING MADE

by modern gray & ductile iron castings!

Block link for chain redesigned to a ductile iron casting eliminated 20 operations, and saved $42,000 in equipment.
The Jeffrey Manufacturing Co.
Changing this compressor discharge casing to a high strength gray iron casting saved 58% in material and 34% in machining costs.
General Electric Company
A cost reduction of up to $20 a set was made by using ductile iron to make these wing-form bodymakers.
National Can Corporation
This oil pump spacer when converted to cast iron eliminated carburizing and finishing operations and saved 88%.
Detroit Diesel Engine Division, GMC.

Four Winners 1957 GIFS Contest

Almost every day design history is being made by gray and ductile iron castings! Modern metallurgy is providing gray irons with new highs in properties . . . new molding techniques are producing castings with better surface finish and closer dimensional accuracy. Such outstanding developments are causing engineers to consider gray and ductile iron *first* in designing products. Write for the GRAY IRON CASTINGS HANDBOOK. Save money by learning more about this remarkable material.

NEW 620 Page Handbook

Just off the press. Cost-cutting design and purchasing information on new ductile, regular and special iron castings. 400 illustrations, 64 tables, 263 subjects. Mail coupon for TEN DAYS FREE EXAMINATION. At the end of 10 days remit $10 or return the book.

GRAY IRON FOUNDERS' SOCIETY INC.
National City-East Sixth Building
Cleveland 14, Ohio

☐ $10 enclosed ☐ bill after 10 days
☐ Purchase Order enclosed

*Name*_____ *Title*_____

*Company*_____

*Address*_____

*City*_____ *Zone*____ *State*_____

TIME TO DESIGN WITH **GRAY IRON CASTINGS**

For more information, turn to Reader Service card, circle No. 540

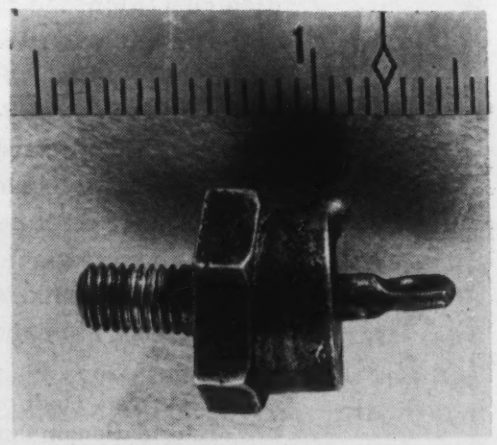
American Cyanamid Co.

***Insulated pipe** for underground systems.*

duced by Temploc, Inc., the pipe is also said to be about 20% less costly than steel pipe.

The pipe, used for underground steam and hot water systems, is insulated with fibrous glass. Around the glass insulation is a jacket of spirally-wrapped glass cloth-reinforced polyester resin which is built up over a sheath of kraft paper.

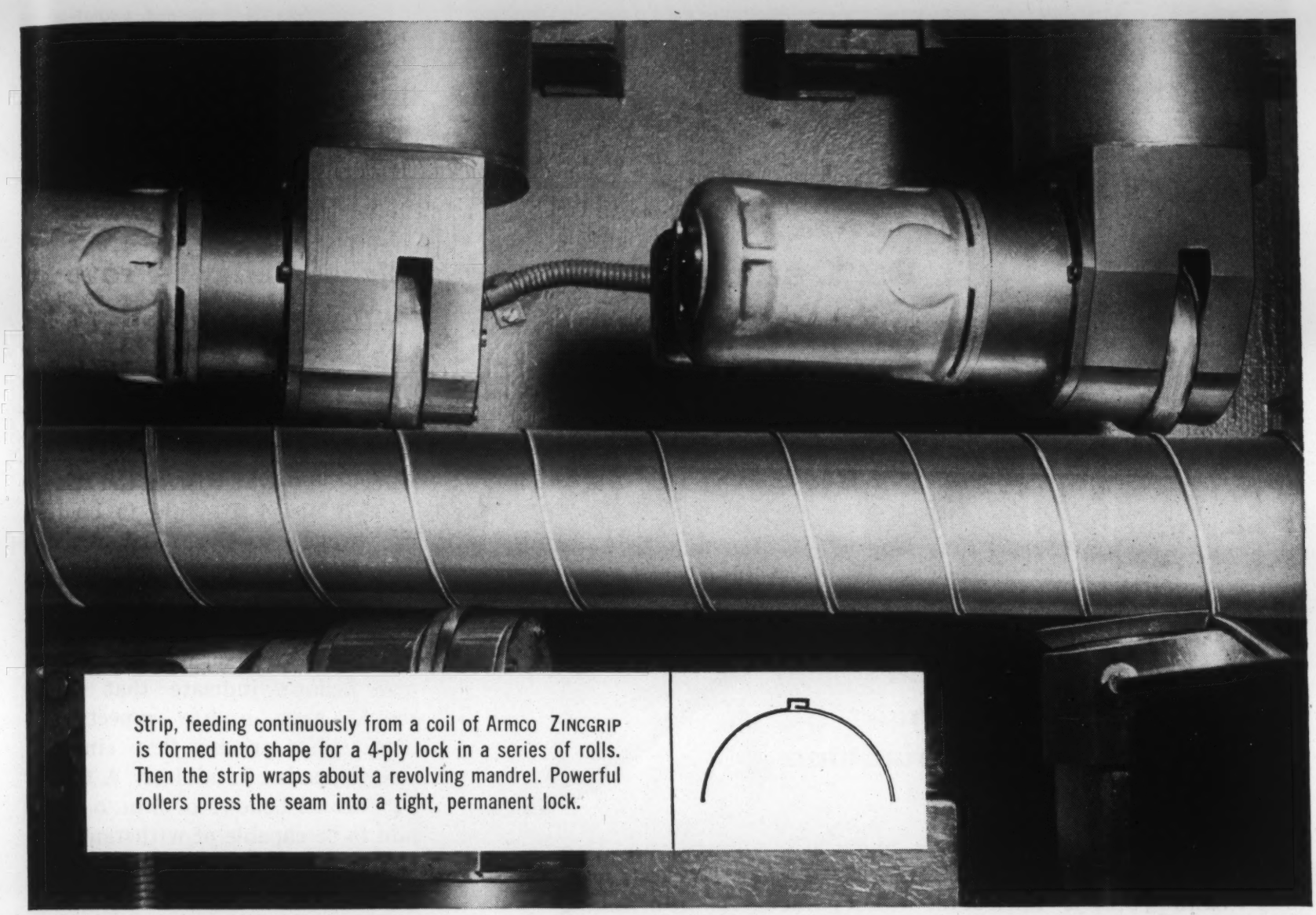
An 8-in. pipe weighs 31 lb per ft; an equivalent galvanized steel shell, tar-insulated pipe weighs 60 lb per ft. The insulated pipe and fittings are available in sizes cus-



Silicon diode resists fire—The 25-amp Westinghouse silicon diode shown in the photo above was installed in an oil-immersed cathodic protection rectifier used to prevent galvanic corrosion of oil pipelines near a Texas refinery. Exposed to a forest fire, the rectifier was completely burned out, the 11-gage steel case was badly warped and the oil burned—but three of the silicon diodes retained their original operating characteristics.

in this continuous lockseaming operation . . .

Zinc coating on Armco ZINCGRIP Steel doesn't flake or peel



Strip, feeding continuously from a coil of Armco ZINCGRIP is formed into shape for a 4-ply lock in a series of rolls. Then the strip wraps about a revolving mandrel. Powerful rollers press the seam into a tight, permanent lock.

Here's in-shop evidence that the zinc coating on Armco ZINCGRIP® Steel clings tightly during severe fabrication.

This machine forms sheet metal into conduit with a continuous spiral lockseam. Few fabricating operations could provide so severe a test for a zinc-coated steel. But Armco ZINCGRIP Steel meets every requirement. Its special hot-dip zinc coating doesn't flake or peel.

This complete zinc protection is doubly important for the conduit. It not only wards off rust when exposed on construction sites, but resists corrosion in areas within buildings where maintenance is difficult or impossible.

If your products require drawing, forming, lockseaming, or any other severe fabrication, you can rely on Armco ZINCGRIP. Just fill in and mail the coupon for full information about this workable, zinc-protected steel.

Other Armco Steels for top-quality products include ZINCGRIP PAINTGRIP®, Stainless Steels, ALUMINIZED STEEL, Cold-Rolled PAINTGRIP, Enameling Iron, Steel Tubing, Electrical Steels, High Strength Steels, Long Ternes, and high-quality Hot- and Cold-Rolled Sheets.

ARMCO STEEL CORPORATION
1348 Curtis Street, Middletown, Ohio

SEND complete information about Armco ZINCGRIP.

Name_____ Title_____

Firm_____

Street_____

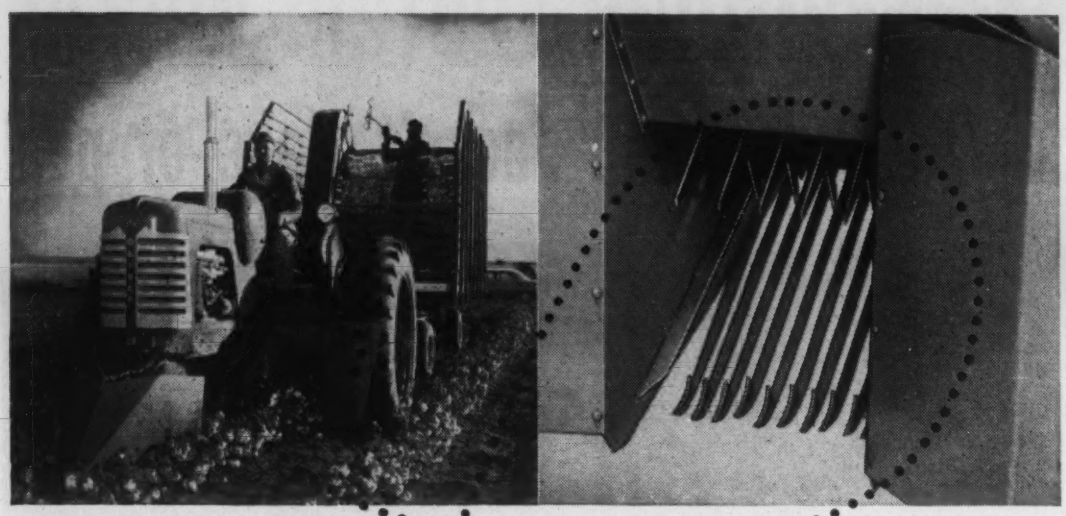
City_____ Zone_____ State_____

ARMCO STEEL

ARMCO STEEL CORPORATION • 1348 CURTIS STREET, MIDDLETOWN, OHIO

SHEFFIELD DIVISION • ARMCO DRAINAGE & METAL PRODUCTS, INC. • THE ARMCO INTERNATIONAL CORPORATION

For more information, turn to Reader Service card, circle No. 444



82% saved... breakage stopped... adjustability gained through Malleable Iron

... all this achieved by Oliver Corporation for one part in their cotton stripper machine

This 30" tooth and 19 others like it in an Oliver Cotton Harvester, strip the cotton bolls from field plants. It is an unusual casting, only ¾" thick at the widest point except the mounting shank. Since making it of Malleable Iron, Oliver has saved 82% on the cost of each tooth, or $136.00 per harvester.

The cotton farmer benefits two ways: the tough malleable teeth do not snap off; and the improved mounting method now possible enables him to adjust their spacing for different types of cotton. *None of these malleable teeth, formerly made of another material, have broken in the harvesters built since their adoption.*

How about Malleable?

Thousands of important parts have been strengthened—improved in appearance—reduced in cost, by manufacturers in many industries. Write for our Value Analysis brochure, filled with examples.

Consult a malleable foundry engineer at the drawing board stage.

Malleable FOUNDERS' SOCIETY

1800 Union Commerce Building **Cleveland 14, Ohio**

For more information, turn to Reader Service card, circle No. 378

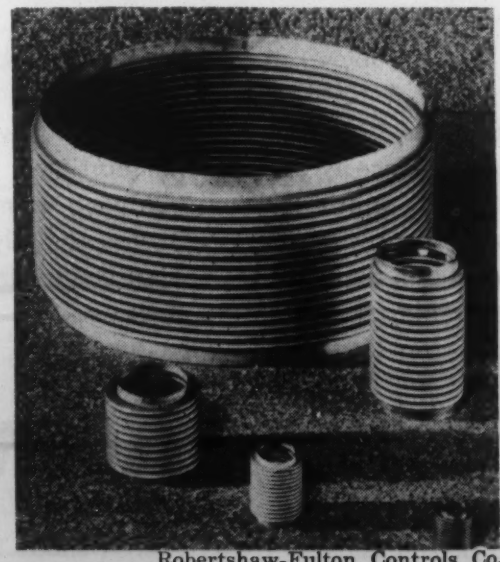
tural and engineering specifications. The outer covering can be tom-cut to meet specific architect-applied to any type of insulation and pipe including iron, steel, copper, brass, etc.

Nickel Bellows Prove Superior to Stainless

Bellows for high temperature, high pressure applications are now being made of Inconel and Inconel X—two nickel-chromium alloys. Chief reasons for the selection of nickel are said to be its exceptional strength and resistance to corrosion at high temperatures.

Results of tests conducted to determine the durability of the new bellows indicate that they should have a life expectancy three times greater than similar bellows made of stainless. A four-ply Inconel bellows of 2-in. o.d. is said to be capable of withstanding 1000 psi at room temperature. Under certain conditions, the bellows may also be used at temperatures as high as 1500 F.

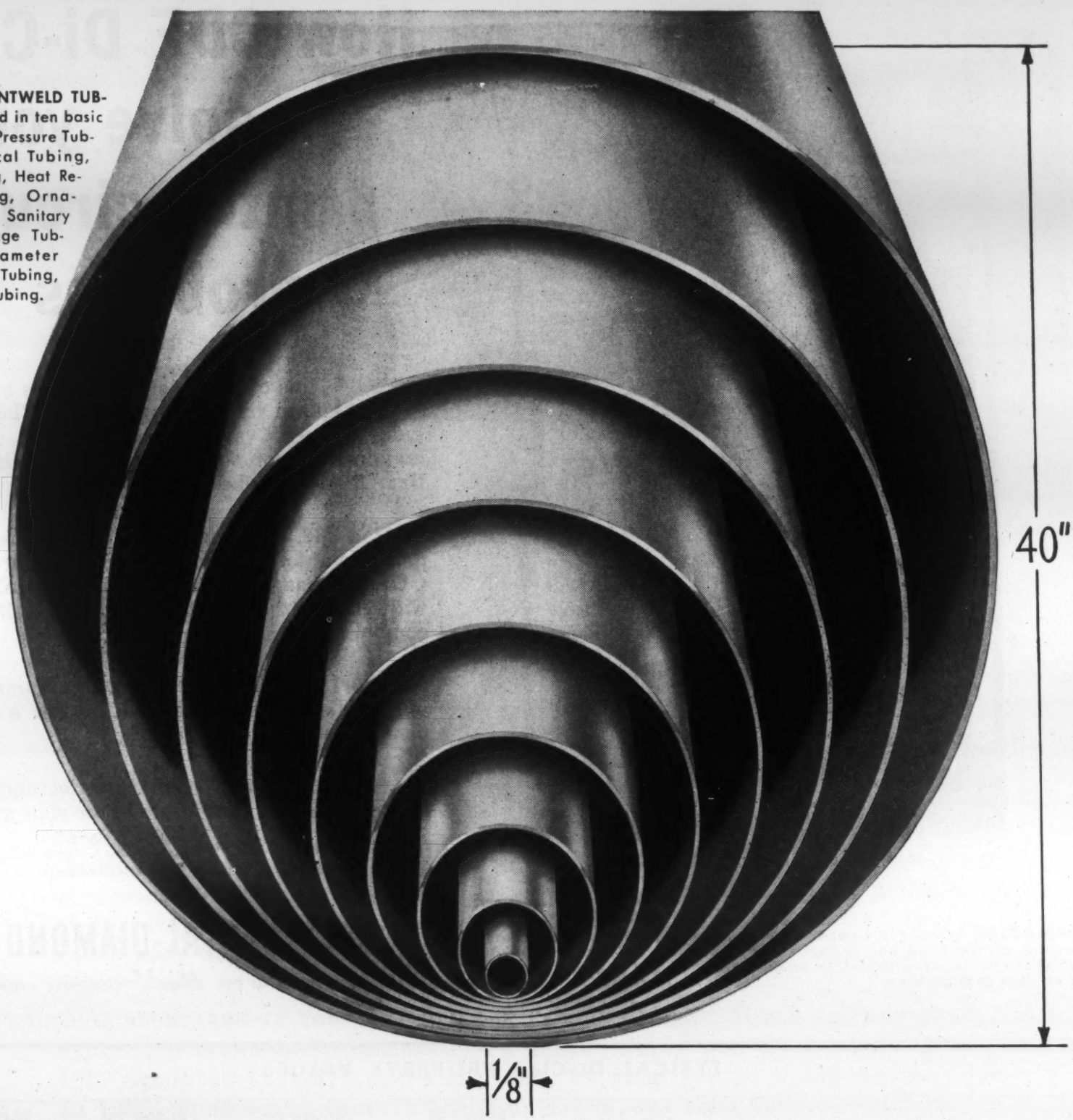
The bellows are available in a variety of sizes from 15/32 to 12 in. o.d. and in single to four plies (see photo). Smaller sizes are seamless; larger bellows are welded.



Robertshaw-Fulton Controls Co.

***Nickel bellows** are available in a variety of sizes.*

CONTOUR TRENTWELD TUBING is furnished in ten basic classifications: Pressure Tubing, Mechanical Tubing, Aircraft Tubing, Heat Resistant Tubing, Ornamental Tubing, Sanitary Tubing, Beverage Tubing, Large Diameter Tubing, Shaped Tubing, and Formed Tubing.



TRENTWELD tubing is equal in strength and has more uniformity than tubing made by any other method of manufacture

Trent offers tubing in sizes ranging from ⅛" to 40" O.D. and in a wide range of grades. These include: Hastelloy,* Zirconium, Zircaloy, Titanium and 19-9-DL grades. All are made by an exclusive welding process—Contour Trentweld®—which virtually eliminates the bead. Furthermore, by cold working and annealing after welding, Trent makes the weld equal in strength and corrosion resistance to the parent metal.

To insure that Trentweld tubing is of the highest quality attainable, a rigorous quality control program is carried out. Samples of each lot are tensile tested. Periodic tests – flattening, reverse bend, flare and flange, coil, and pressure – are conducted. Rigid corrosion tests are made on all lots intended for corrosive applications. When requested, a unique "single-wall" X-ray inspection is made as your final assurance of a sound, uniform product.

Why not take advantage of Trent *quality* when you order stainless or high alloy tubing? For further information, write for the Trent tubing handbook, Trent Tube Company, East Troy, Wisconsin.

*Trademark of Haynes Stellite Co.

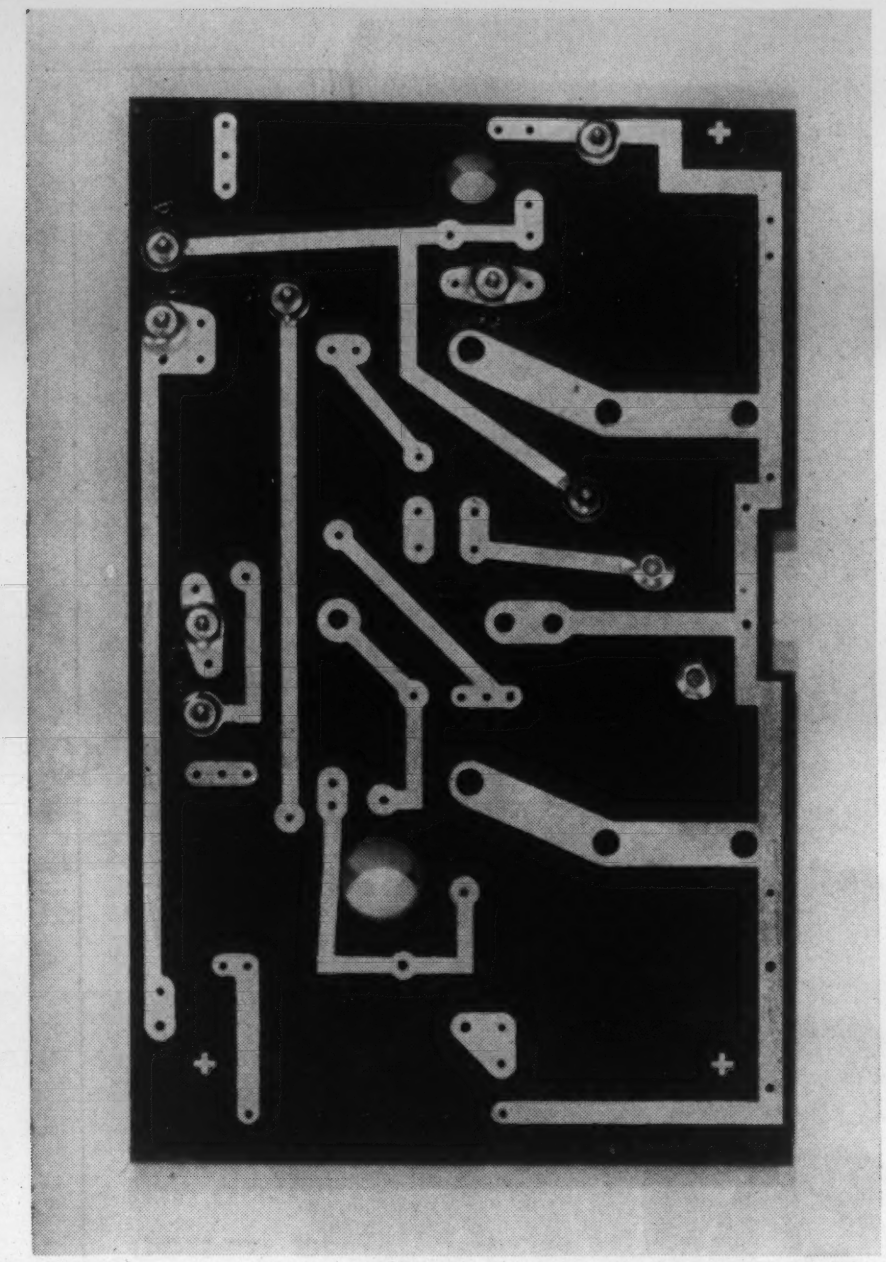
CONTOUR TRENTWELD

TRENT TUBE COMPANY

Subsidiary of Crucible Steel Company of America

GENERAL OFFICES: EAST TROY, WISCONSIN
MILLS: EAST TROY, WIS.; FULLERTON, CALIF.

For more information, turn to Reader Service card, circle No. 470



How CDF Di-Clad† can solve your printed-circuit problems

The CDF line of copper-clad laminates in all grades is now known by a new name—Di-Clad. Di-Clad grades meet the varying needs of design, production, and operation of electronic equipment. Grades other than those described are also available.

Di-Clad 28E. For high mechanical strength, low moisture-absorption, and good insulation resistance, CDF Di-Clad laminates of epoxy resin laminated with glass fabric offer the designer a strong, reliable combination.

Di-Clad 112T. A Teflon* glass-fabric laminate offering the best dielectric properties over a wide temperature and frequency range.

Send us your requirements and let our engineers help you select the right grade for your application.

†Trademark of Continental-Diamond Fibre Corporation
*Du Pont trademark for its tetrafluoroethylene resin.

Di-Clad 2350. An economy paper-base phenolic grade having good tensile, flexural, compressive, and impact strength. Adequate for most non-critical printed-circuit applications. Can be cold punched and sheared up to 5/64 of an inch in thickness.

CONTINENTAL-DIAMOND FIBRE
A SUBSIDIARY OF THE Budd COMPANY • NEWARK 25, DEL.

TYPICAL Di-Clad PROPERTY VALUES

	Di-Clad 2350	Di-Clad 26 (NEMA XXXP)	Di-Clad 28 (NEMA XXXP)	Di-Clad 28E (NEMA G-10)	Di-Clad 112T Teflon*
BOND STRENGTH—0.0014" foil (lbs. reqd. to separate 1" width of foil from laminate)	6 to 10	6 to 10	6 to 10	8 to 12	4 to 8
MAXIMUM CONTINUOUS OPERATING TEMPERATURE (Deg. C.)	120	120	120	150	200
DIELECTRIC STRENGTH (Maximum voltage per mil for 1/16" thickness)	800	900	850	650	700
INSULATION RESISTANCE (Megohms) 96 hrs. at 35°C. & 90% RH (ASTM D257, Fig. 3)	500	150,000	600,000	100,000	75,000
DIELECTRIC CONSTANT 10^6 Cycles	4.5	4.0	3.6	4.9	2.6
DISSIPATION FACTOR 10^6 Cycles	0.040	0.026	0.027	0.019	0.0015
ARC-RESISTANCE (Seconds)	5	10	10	130	180
TENSILE STRENGTH (psi.)	18,000	16,000	12,000	48,000	23,000
FLEXURAL STRENGTH (psi.)	27,000	21,000	18,000	70,000	13,000
IZOD IMPACT STRENGTH edgewise (ft. lbs. per inch of notch)	0.80	0.45	0.42	12.0	6.0
COMPRESSIVE STRENGTH flatwise (psi.)	32,000	28,000	25,000	62,000	20,000
BASE MATERIAL OF LAMINATE	Paper	Paper	Paper	Medium-weave, medium-weight glass cloth	Fine-weave, medium-weight glass cloth
COLOR OF UNCLAD LAMINATE	Natural	Natural greenish	Natural	Natural	Natural

All these standard grades are available with 0.0014" and 0.0028" or thicker electrolytic or rolled copper foil on one or both surfaces. Other metal foils and other resin-and-base combinations can be supplied on special order.

*Du Pont Trademark

For more information, turn to Reader Service card, circle No. 519

PRICES AND SUPPLY

...AT A GLANCE

STEEL CONSUMPTION IN 1958 WILL JUST ABOUT EQUAL THAT OF 1957, according to B. C. Estes, director of staff administration, U. S. Steel Corp. However, steel production during 1958 should decrease by about 5%. Reason for the disparity is that steel consumers are expected to utilize a good portion of their inventories this year.

. . . AND STEEL PRICES ARE HEADED FOR A $7 PER TON INCREASE this summer, according to Avery C. Adams, president, Jones & Laughlin Steel Corp. At midyear, steelworkers will receive an additional wage boost under their three-year contract with steel producers. W. W. Holloway, chairman of Wheeling Steel Corp., says that the steel price increase of $6 per ton put into effect last July was "wholly inadequate" to cover wage boosts at that time.

RUBBER CONSUMPTION IN 1957 REACHED THE SECOND HIGHEST TOTAL for any year, according to Rubber Manufacturers Assn. Total use of new rubber in 1957 amounted to 1,475,000 long tons, as compared to 1,436,482 in 1956. In 1955, the record year, a total of 1,529,699 long tons of rubber were consumed. Based on the present rate of increase, RMA estimates that by 1960 U. S. rubber consumption will reach 1,635,000 long tons annually.

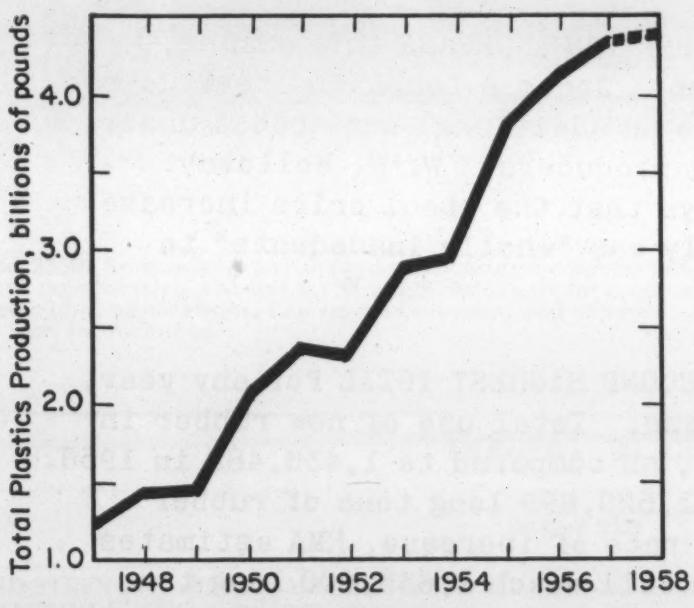
PRICE OF PLATINUM HAS BEEN REDUCED AGAIN by Baker & Co. This latest reduction lowers the price from $82-87 to $77-80 per oz; last July the price of platinum was decreased by $3 per oz. Reason for the present reduction seems to be a falling off of demand to levels considerably below present supply, especially in the oil refining industry.

THE PROPORTION OF SYNTHETIC RUBBER USED continues to increase. In 1955, the ratio of synthetic rubber use to total rubber use was 58.50%; in 1956, it was 60.87%; and in 1957 it rose to more than 63%. Actual figures for 1957 show synthetic rubber consumption of 934,000 long tons, as compared to 541,000 long tons of natural rubber.

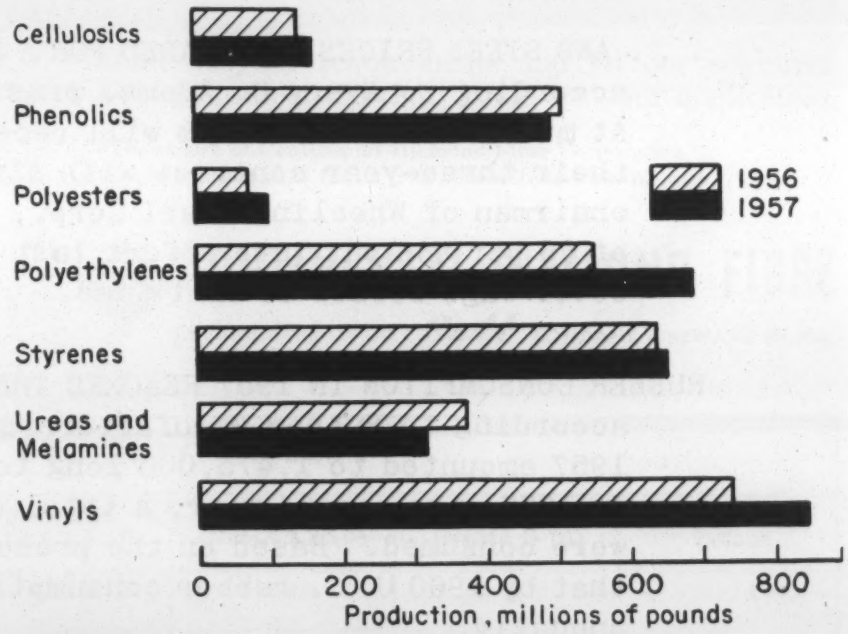
HIGH GRADE ZIRCONIUM SPONGE for nuclear reactors is now available for immediate delivery at the lowest price yet, according to Niles

C. Bartholomew, vice president of Carborundum Metals Co. The new price, representing the third major reduction in the last four years, is $7.50 per lb for 100-lb lots—approximately one-third the 1953 price.

COPPER PRICES CONTINUE TO DROP despite earlier indications of a reversal. Toward the latter part of January, custom smelter price dipped to 24¢ per lb. Almost simultaneously, Phelps Dodge Corp., the nation's second largest copper producer, cut its Arizona mine production by 1700 tons a month. "Decreased demand for the metal" was given as the reason. In 18 months Phelps Dodge has made four production cuts totaling 22%, or roughly 5100 tons a month.



***Production** of all plastics materials from 1947 to 1958. Figures for 1958 based on SPI estimates.*



***Comparison** between 1956 and 1957 production of some basic plastics.*

Plastics Production Up in '57, Will Level Off in '58

■ Although plastics production went over the four billion pound mark for the second year in succession, there is every indication that a leveling off period has now set in.

According to the Society of the Plastics Industry, Inc., total production in 1957 amounted to 4,387,000,000 lb, or an increase of only 7% over the 4,124,000,000 lb produced in 1956. Production in 1956 ended up 10% higher than production in 1955, and production was 30% higher in 1955 than in 1954. For 1958, SPI estimates an increase of only 1 or 2%. Statistics on the sale of molds, generally regarded as an indication of future trends, show an increase in 1957 of only 2½% over 1956, as contrasted with a 16% increase in 1956 over 1955.

1957 developments

Although the plastics "boom" seems to have been slightly lowered, several interesting developments took place in 1957. For one thing, 1957 marked the beginning of the commercial availability of high density polyethylene. According to SPI, the availability and wide use of this new material may very well have been responsible

(continued on p 202)

Prices of Materials

Changes since last month are bold-faced

NONMETALLICS

Prices for large quantities for range of grades, color, sizes; given in $/lb

RUBBER

Material	Dry	Latex
Butadiene-Acrylonitrile	.49-.65	.46-.54
Butadiene-Styrene	.17-.30	.22-.32
Butyl	.23-.28	—
Neoprene[a]	.39-.75	.37-.47
Silicone[a]	1.90-4	—
Polysulfide[a]	.47-1	.70-.92
Natural	.29[b]	—

[a]Less than carload quantities.
[b]Average spot price for month of Jan.

GLASS FOR REINFORCED PLASTICS

Fabric ($/yd 38 in. wide)[a]	
112 Woven	.48
181 Long-shaft satin weave	1.03
143 Unidirectional	1.00
Roving[a]	
Continuous	.40
Continuous spun strand	.36
Continuous chopped spun	.38
Milled fibers (1/32-¼ in.)[a]	.45
Mat	
Chopped strand (2 in.)[a,b]	.52-.72
Surfacing ($/1000 sq ft)[c]	10-19
Continuous chopped strand (¼-2 in.)	.40

[a]Price includes binder or finish.
[b]Price varies with binder.
[c]0.010-0.020 in. thick.

THERMOSETTING PLASTICS

Material	Molding Compounds	Laminating, Casting Resins
Alkyd	.34-.53	—
Epoxy	—	.45-.80
Melamine	.42-.45	.40-.41
Phenolic	.21-.40	.17-.34
Polyester	.42	.32-.50
Silicone	2.75-5.40	1.55-1.74[a]
Urea	.19-.33	—

[a]60% solids content.

All prices are approximate and given solely for general guidance of those responsible for materials selection.

THERMOPLASTICS

Material	Molding Compounds	Sheet (.030-.250 in.)	Rod		Tube	
			⅛-¼ in.	⅜-1¼ in.	⅛-¼ in.	⅜-1¼ in.
Acrylic	.51-.59	.49-2.15	.90-1.15	.80-.90	1-1.15	.90-1
Cellulosic						
Acetate	.36-.65	.92-1.16	.75-1	.65-.75	.85-1	.75-.85
Butyrate	.50-.72	1-1.28	.95-1.20	.85-.95	1.05-1.20	.85-1.05
Nitrate	—	1.60-2.73	1.45-1.75		2.25-5.00	
Propionate	.51-.63	—	—		—	
Fluorocarbon						
CFE	7-8	15-23	18-22	14-20	20-22.50	16-20
TFE	4.50-7.45	14.30-11	13	13	13	13
Nylon	1.18-2.30	—	3	3	3	3
Polyethylene	.35-.56	.85-1	.75-1	.65-.75	.85-1	.75-.85
Polystyrene	.26-.44	.57-.61	.65-.90	.55-.65	.75-.90	.65-.75
Vinyl	.27-.43	.62-.92	.75-1	.65-.75	.85-1	.75-.85

NONFERROUS METALS

Mill base prices for large quantities; given in $/lb except where indicated

ALUMINUM

Pig (99-99.9%)	.26-.28
Ingot (99-99.9%)	.28-.30
Foil (5-0.5 mil)	.55-.77
Alloy Ingot (13, 43, A132, 214)	.29-.32
Sheet (1100, 3003; 3-0.03 in.)[a]	.43-.47
Plate (1100, 3003, 5050, 3004, 5052)[a]	.40-.43

[a]Mill finish.

BRASS

Form	Cart., 70%	Low, 80%	Red, 85%
Sheet, Strip	.43	.45	.46
Seamless Tubing	.46	.48	.49
Rod (not f.c.)	.44	.45	.46
Wire	.43	.45	.46

COPPER

Ingot (elec)	.25
Sheet, Strip (hot rolled)	.48
Seamless Tubing	.48
Rod, Drawn	.45
Rod, Free Cutting	.57
Wire	
Round	.30
Square, Rectangular	.32
Magnet	.38

LEAD

Common Grade	.13

MAGNESIUM

Pig (98.8%)	.35-.36
Ingot (98.8%)	.36-.37
AZ91B Ingot (die casting)	.37
AZ91C Ingot (sand casting)	.41[a]

[a]Delivered price.

NICKEL

Form	"F"	"A"	Monel
ingot	.75[a]	—	—
Rod	—	1.07	.89
Sheet, C.R.	—	1.26	1.06
Strip, C.R.	—	1.24	1.08
Seamless Tube	—	1.57	1.29

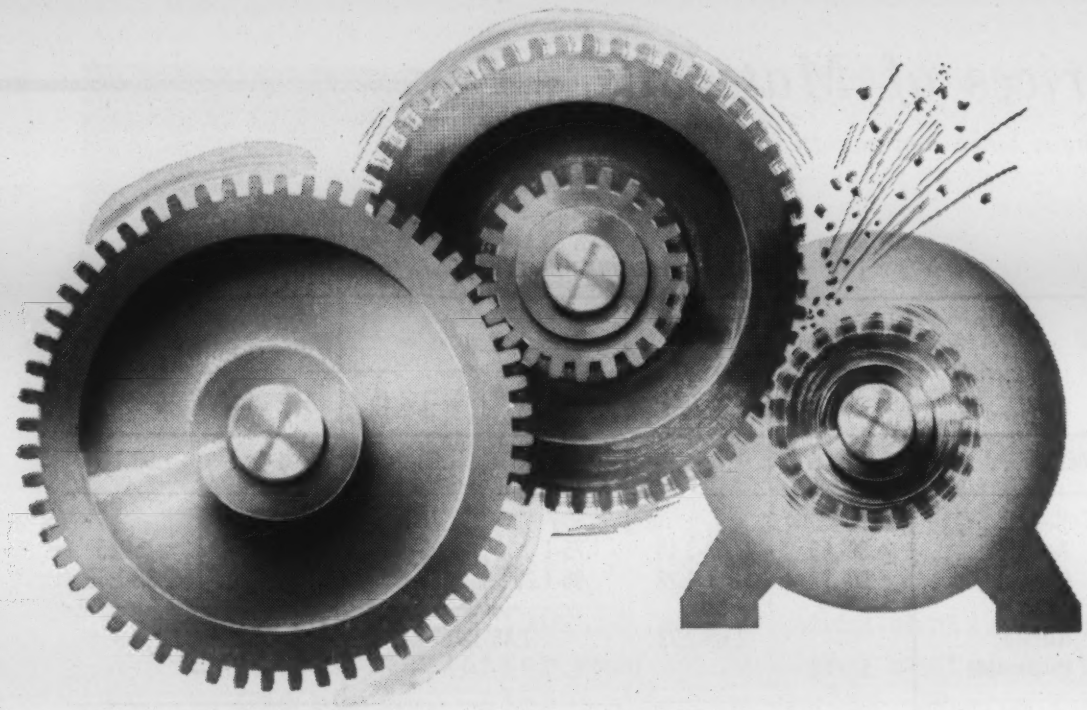
[a]Delivered price.

TIN

Primary[a]	.92

[a]Delivered price.

(continued on p 196)



Protect Gear Trains and Equipment with a gear made of Taylor Laminated Plastic. This unit will act as a *safety valve*, localize the effects of destructive forces. Yet, under normal conditions, the gear will outwear metal ones.

Put a safety valve in your gear train

A gear made of Taylor Laminated Plastic Silent Gear Stock will localize damage due to destructive stresses, yet outwear metal under normal operating conditions

What gives when gears jam—the power train, the equipment they are in, or a single easy-to-replace gear? It can be the single gear when you install one made of Taylor Laminated Plastic Silent Gear Stock as a *safety valve*. This gear will localize the destructive forces and can even disintegrate—but the other gears in the train, and the equipment, will be fully protected. Yet under normal operating conditions this laminated plastic gear will outwear the metal ones.

Taylor Laminated Plastic Silent Gear Stock is made in several grades. Each has physical and mechanical properties that make it particularly adaptable to such application as gears, cams, pulleys, pinions, flat springs, and bearings.

Look into the advantages of Taylor Fibre Co. and its facilities for producing laminated plastics in mechanical, electrical and combination grades and parts fabricated from them. At your disposal will be engineering assistance and the convenience of integrated operations at both plants—Norristown, Pa., and La Verne, Calif. Contact TAYLOR FIBRE CO., Norristown 41, Pa., for complete information.

TAYLOR
Laminated Plastics
Vulcanized Fibre

PHENOLIC-MELAMINE-SILICONE-EPOXY LAMINATES • COMBINATION LAMINATES • COPPER-CLAD LAMINATES • VULCANIZED FIBRE

For more information, turn to Reader Service card, circle No. 416

PRICES AND SUPPLY

TITANIUM

Sponge (99.3+%)	1.65-2.50
Bars, Rod	6.15-6.40
Plate	8.00-10.75
Sheet, Strip	9.50-11.10
Wire	7.50-8.00

ZINC

Prime Western	.10½[b]
Die Casting Alloys[a]	.13-.14
Sheet	.24
Ribbon	.21
Plates	.19

[a]Alloys 2, 3, 5. [b]Delivered price.

METAL POWDERS

Aluminum [a,b]	.40
Brass [a]	.31-.38
Copper (elec or red.)[a]	.41
Molybdenum (98%)	3.80-4.10
Nickel	1.05
Tantalum	49
Tungsten (C-red. 98.8%; H_2-red. 99+%)	3-4[c]
Zirconium	
Flash Grade	11.50
Electronics Grade	15

[a]Price for −100 mesh. [b]Freight allowed. [c]Delivered price.

OTHER NONFERROUS METALS

Cadmium (bars)	1.55
Columbium	55-85
Gold	$35/troy oz
Indium (99.97+%)	$2.25/troy oz
Manganese (99.9%)	.34[a]
Palladium	$19-21/troy oz
Platinum	$77-80/troy oz
Silver	89-91¢/troy oz
Tantalum (sheet, rod)	55-60
Vanadium	80
Zirconium (sheet, strip, bar)	25-35

[a]Delivered price.

IRONS AND STEELS

Mill base prices for large quantities

SEMIFINISHED STEEL ($/net ton)

Ingots, Alloy	77
Billets, Blooms, Slabs	
Carbon, Re-Rolling	77.50
Carbon, Forging	96
Alloy, Forging	114
Seamless Tube Rounds	117.50
Wire Rods	$6.15/cwt

(continued on p 198)

Engineering problem:

Pressure-tight fastening of transit cases

The solution:

A specially modified LINK-LOCK

Applied Design Company engineers worked with Simmons to develop this successful LINK-LOCK application

Simmons LINK-LOCK, with design modifications developed in cooperation with the Engineering Department of Applied Design Company, Buffalo, New York, resolves special closure requirements in rigidly specified transit cases like the aluminum equipment container shown.

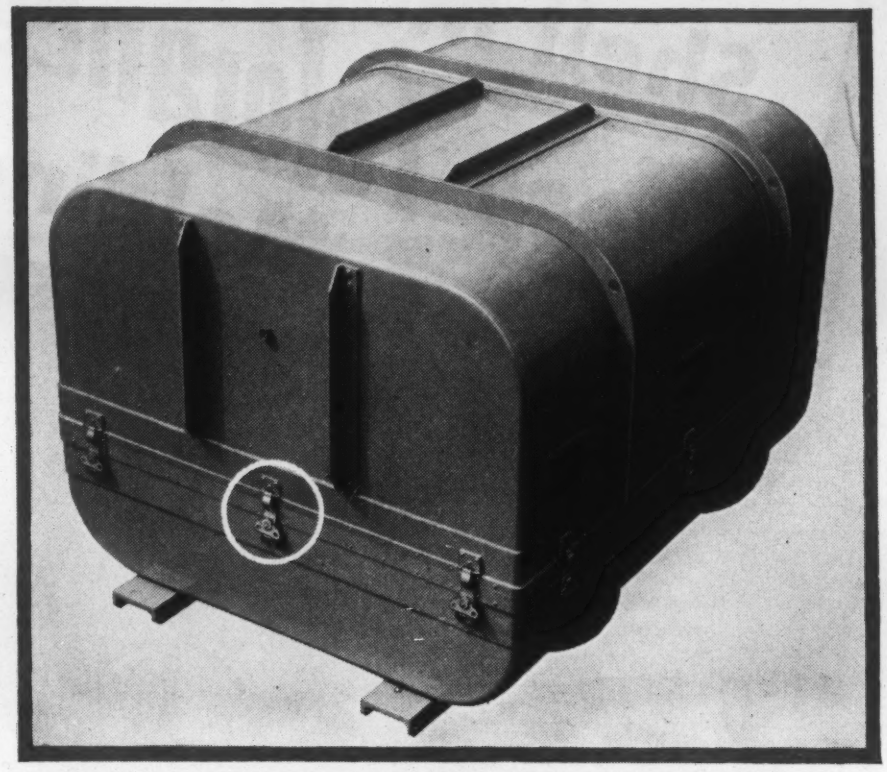
Here, the bowed LINK-LOCK engagement blade provides the double advantage of maintaining constant fastener pressure and permitting considerable mounting tolerance. This container is just one of many important products in which Applied Design specifies standard and special Simmons Fasteners.

Here's why LINK-LOCK is ideal for use on military cases produced to exacting specifications as well as on inexpensive commercial containers:

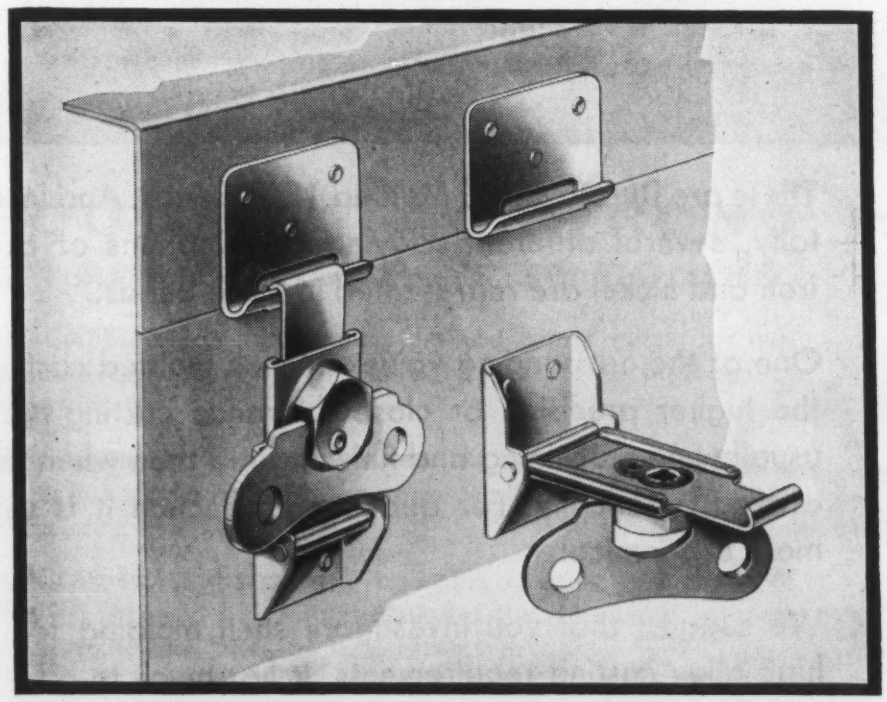
- Impact and shock resistant (positive-locking).
- High closing pressure with light operating torque... insures pressure-tight seals where required.
- Available in 3 sizes, for heavy, medium, and light duty.
- Compact design... lies flat against case even when unlocked.
- Opening and closing by wing-nut, screwhead, or hex nut.
- Flexible engagement latch design... can be varied to suit different conditions.

Also available: Spring-Loaded LINK-LOCK. Ideal for the less expensive containers where costs won't permit precision production. Spring provides take-up to compensate for set in gasketing, irregularities of sealing surfaces, and mounting inaccuracies.

SEND TODAY for the Simmons Catalog for complete information and engineering data on LINK-LOCK and other Simmons Industrial Fasteners. Engineering service is available; outline your particular fastening problems. Samples on request.



Twelve special loop-blade LINK-LOCK fasteners are used in this aluminum transit case designed by Applied Design Company.



Standard No. 2 LINK-LOCK (Medium-Duty). Available with screwhead, wing-nut as shown, or hex nut.

Visit us at Booth 1020
DESIGN ENGINEERING SHOW
International Amphitheatre, Chicago
April 14-17, 1958

SIMMONS

FASTENER CORPORATION

1759 North Broadway, Albany 1, New York

QUICK-LOCK • SPRING-LOCK • ROTO-LOCK • LINK-LOCK • DUAL-LOCK • HINGE-LOCK

See our 8 page catalog in Sweet's 1958 Product Design File

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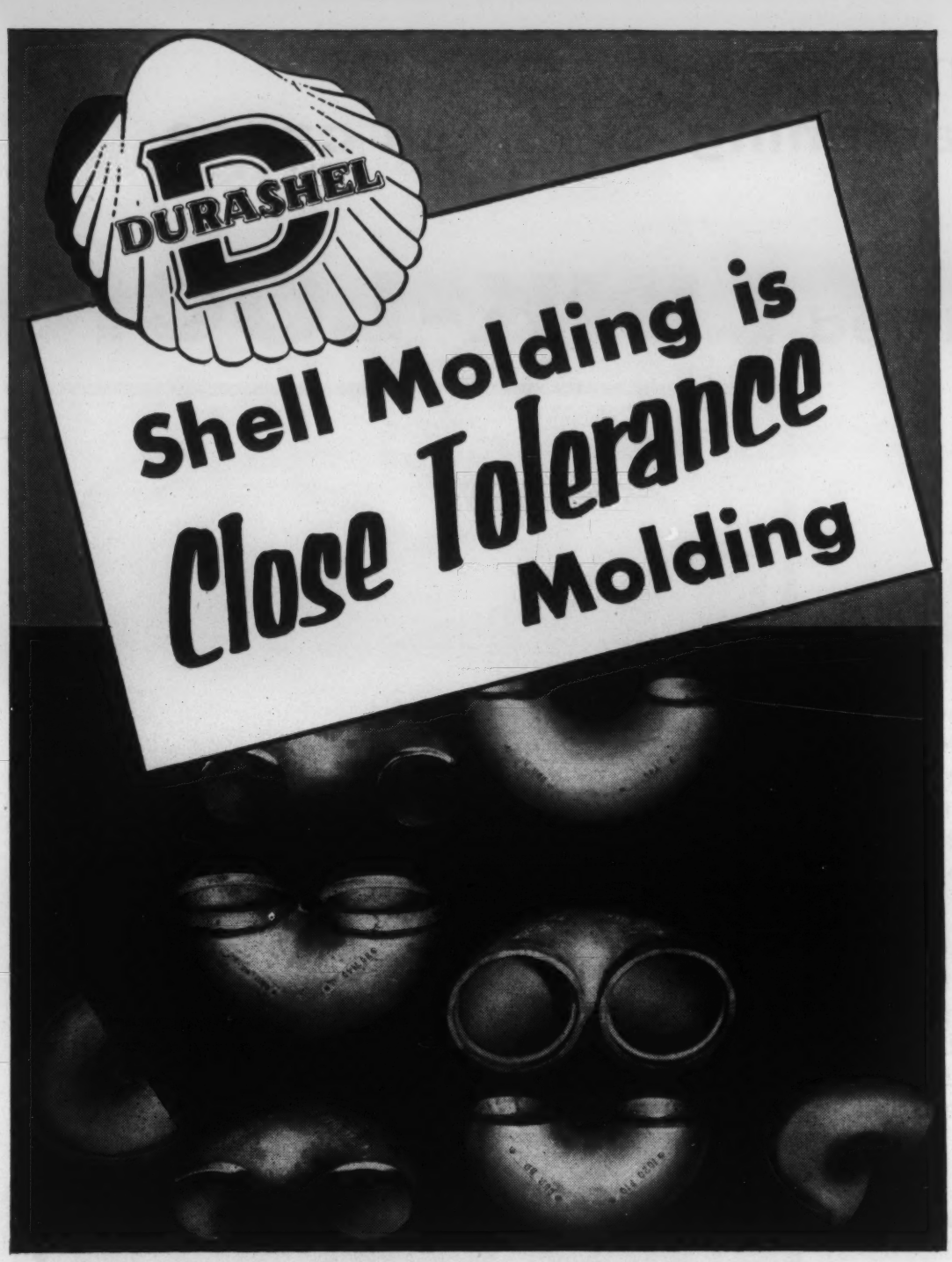


These are Duraloy Shell Molded 180° Bends. And incidentally, several different alloying combinations of chrome iron and nickel are represented in these bends.

One of the outstanding values in shell molded castings is the higher precision or close tolerance casting . . . also usually less machining and finishing . . . than when pieces are cast statically. For quantity production it is usually more economical.

We suggest that you investigate shell molding for your high alloy casting requirements. It has much to offer and we have complete facilities for taking care of your requirements. Should other casting methods—static or centrifugal be better, we have these facilities, too.

The DURALOY Company

OFFICE AND PLANT: Scottdale, Pa.

EASTERN OFFICE: 12 East 41st Street, New York 17, N. Y.
ATLANTA OFFICE: 76—4th Street, N.W.
CHICAGO OFFICE: 332 South Michigan Avenue
DETROIT OFFICE: 23906 Woodward Avenue, Pleasant Ridge, Mich.

For more information, turn to Reader Service card, circle No. 456

PRICES AND SUPPLY

FINISHED STEEL ($/cwt)

Form	Carbon	High Str Low Alloy	Alloy
Plate	5.10	7.62	7.20
Sheet, H.R.	4.92	7.27	—
Sheet, C.R.	6.05	8.97	—
Strip, H.R.	4.92	7.32	8.10
Strip, C.R.	7.15	10.65	—
Bar, H.R.	5.42	7.92	6.47
Bar, C.F.	7.30	—	8.77

STAINLESS STEELS ($/lb)

Material	Forging Billets	H. R. Bars	Plate	Sheet, Strip
Austenitic				
301, 302, 302B, 303, 304, 305	.38-.41	.44-.48	.46-.51	.51-.59
321[a]	.47	.56	.60	.66
347[a]	.56	.65	.70	.80
Martensitic				
410[a]	.28	.34	.35	.40
416	.29	.34	.35	.47
403	.32	.38	.40	.48
420, 440	.34	.41	.45	.62
Ferritic				
405, 430, 430F[a]	.30	.34-.35	.36-.38	.41-.47
442	.32	.38	.40	.56
431	.30	.35	.46	.54
446	.38	.45	.46	.67
High Mn				
202[a]	.37	.43	.45	.49
Extra Low C				
304L	.48	.56	.59	.63
316L	.70	.81	.85	.89
Precip Hard.				
17-7PH	.66	.73	.85	.90
PH 15-7 Mo	.86	.93	1.11	1.16

[a]Ingot price approx 60% of billet price.

METAL POWDERS ($/lb)[a]

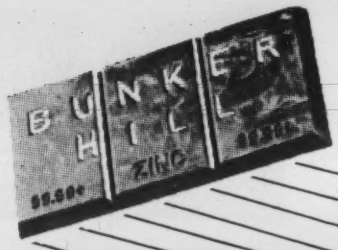
Sponge Iron	.10-.11
Electrolytic Iron	
Annealed (99.5%)	.37
Unannealed (99+%)	.36
Stainless Steel	
304	1.02
316	1.20

[a]Price for —100 mesh.

IRON ($/gross ton)

Pig	65-66

(continued on p 200)



MAKE **DIE-CASTING** THE PROCESS

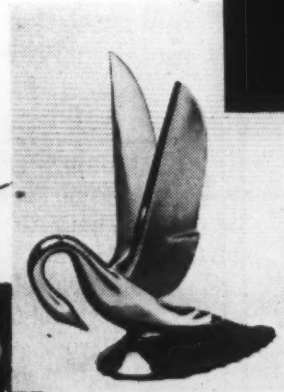
SELECT **ZINC** AS THE BASE METAL

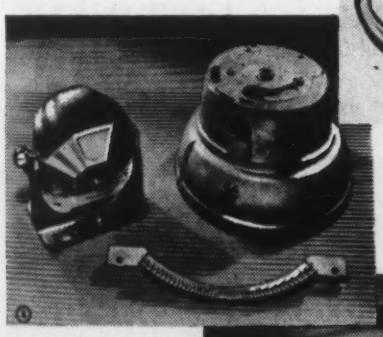
INSIST UPON

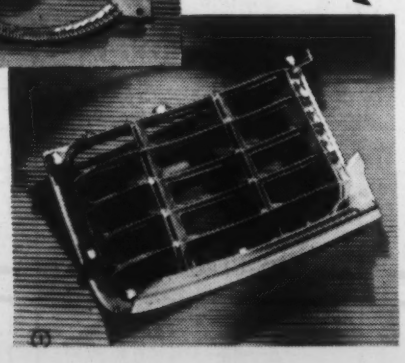
BUNKER HILL

THE

99.99+% ZINC







YOU CAN'T GO WRONG on any of these three counts:

DIE-CASTING as the forming method offers numerous mechanical and economic advantages over other methods of manufacture.

ZINC as the base metal produces die-castings with property values superior to those of the other die-casting metals in many categories.

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The American Zinc Institute, 60 East 42nd Street, New York 17, New York, has available a very interesting 28-page brochure, "Die-Casting-Molten Metal to Finished Part—Direct." We suggest that you send for it. It contains helpful technical information.

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DIVISION OF CRUCIBLE STEEL COMPANY OF AMERICA
P. O. BOX 977 — SYRACUSE 1, N. Y.
SYRACUSE 8-2573

March 27, 1957

Norton Company
Worcester 6
Massachusetts

Gentlemen:

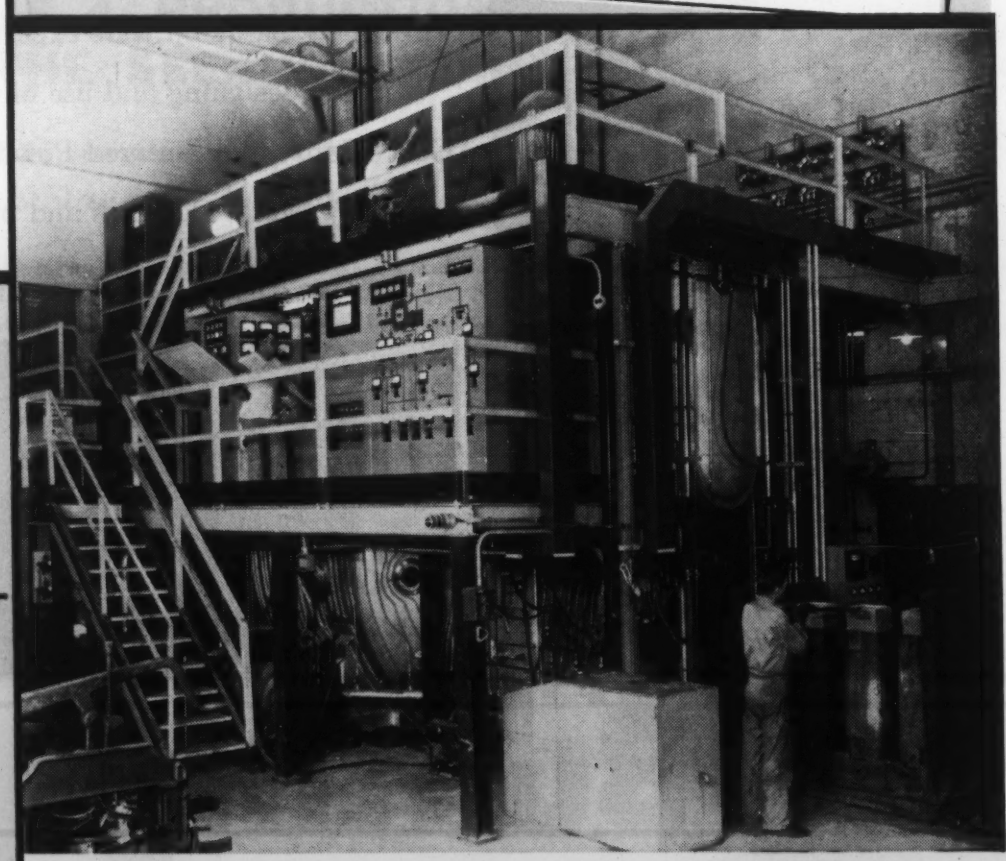
I am enclosing a general view of our newest vacuum melting furnace and a view of the crucible during a melt. This furnace is the largest high vacuum induction furnace in the country and has a capacity of 3000 pounds per heat.

We have successfully used a Norton ramming mix for rammed linings in this and in our 700 pound furnace. Your prefired shapes of Magnorite and Alundum have been used for pouring lips and pouring tubes. Your refractory ramming mixes have been used as a backing for Norton Magnorite and Alundum crucibles in laboratory furnaces for nearly ten years. We have been well pleased with the quality and performance of your products.

Very truly yours,

A. E. Franks
Division Superintendent

AEF/a
cc: Michael Stumm



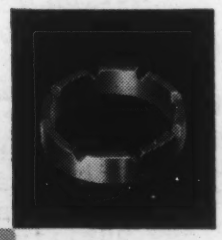
Largest of all high vacuum induction furnaces in the U.S. The accompanying letter from Vacuum Metals Corporation, a Division of Crucible Steel Company, describes how Norton refractory cements and prefired shapes aid in the advanced performance of this huge, modern metal-melting equipment.

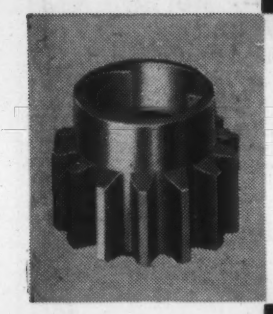
a new expanded field of

BEARING DESIGN and APPLICATION

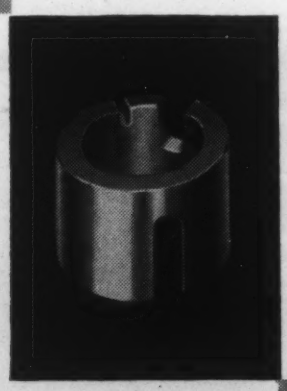
The inauguration of Bunting's new facility for engineering and manufacturing bearings and parts of Sintered Powdered Metals opens a wide new area of opportunity to all mechanical industry.

Sintered Powdered Metal Bearings and parts offer real economies in design. Bunting Engineering and manufacturing skill and traditional technical responsibility assure your most advantageous use of this material.

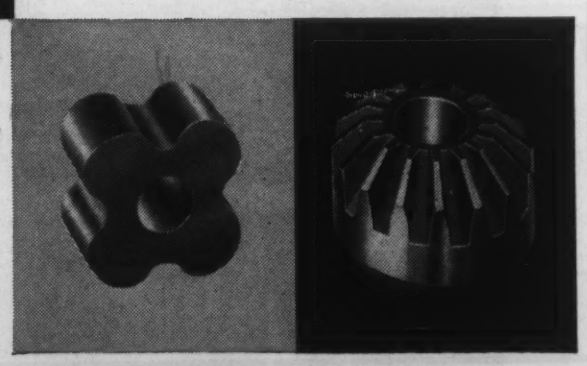




A competent group of Bunting Sales Engineers in the field and a soundly established Product Engineering Department put at your command, comprehensive data and facts based on wide experience in the designing and use of both Cast Bronze and Sintered Powdered Metal Bearings and parts.



Write for catalogs and your copy of the new 24 page Bunting Engineering handbook of Sintered Powdered products and their composition, manufacture and application.



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PRICES AND SUPPLY

Plastics—continued from p 194

for the unusually small increase in polystyrene production (see accompanying chart). Polypropylene, another new material, made its appearance late in 1957 and quantity production is expected in the near future.

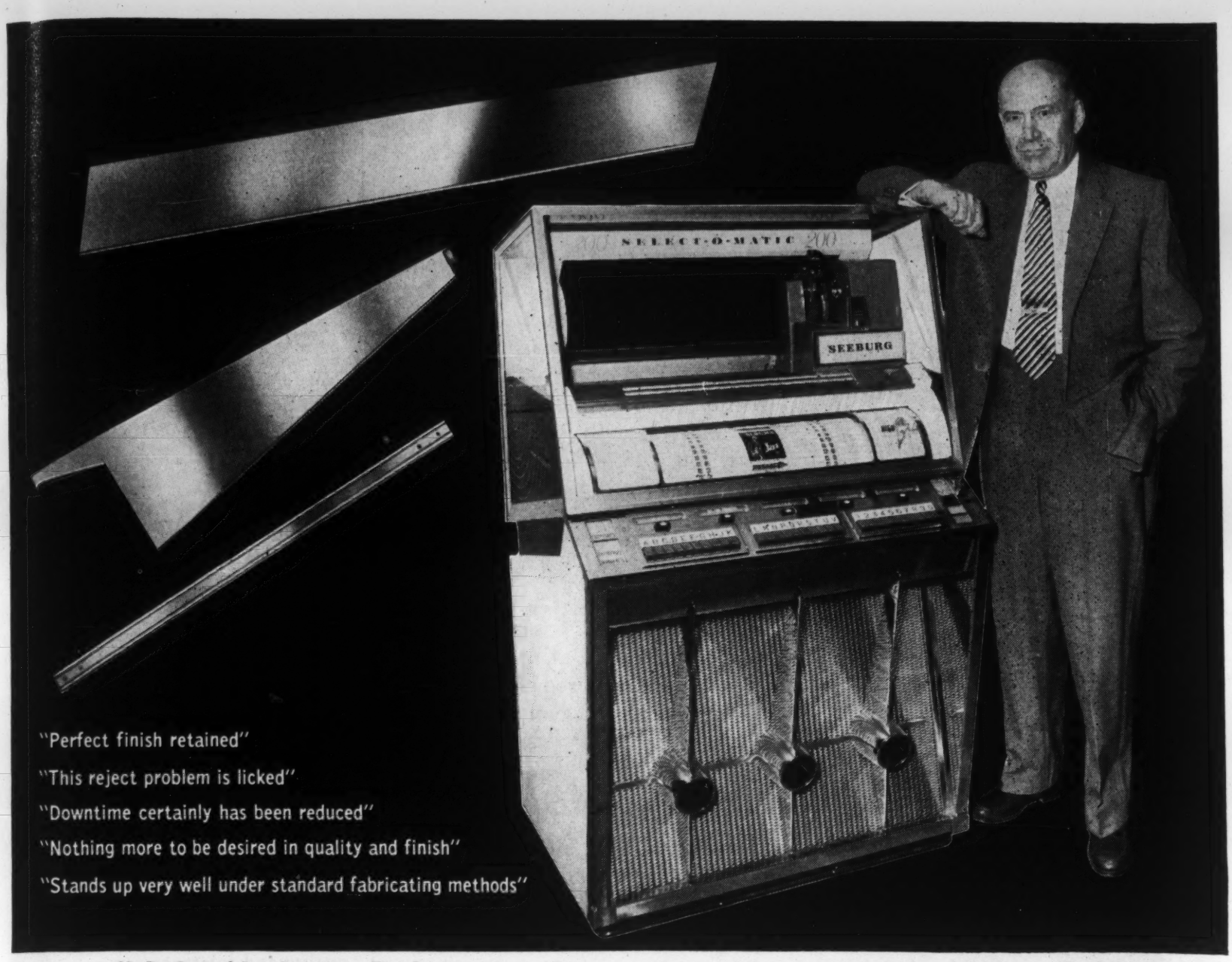
Perhaps the most spectacular development in 1957 was the increased usage of foamed plastics. Total production of all types of foamed plastics exceeded 30 million pounds—an increase of approximately 100% over the 16 million pounds produced in 1956. In 1958, production is expected to reach about 40 million pounds.

In terms of specific materials, polyester resins showed the sharpest percentage gain (up 30.7%) and phenolics the sharpest decrease (down 7.1%). The huge increase in polyester production was due largely to the increased use of reinforced plastics in 1957 (see MATERIALS IN DESIGN ENGINEERING, Feb '58, p 212). Polyethylene production increased substantially (up 22.6%) while polystyrene production increased only very slightly (up 1.1%). Cellulosics bounced back after a decline last year (up 3.5%), but ureas and melamines declined for the second year in a row. Production of vinyls increased again (up 11.8%).

Outlook for 1958

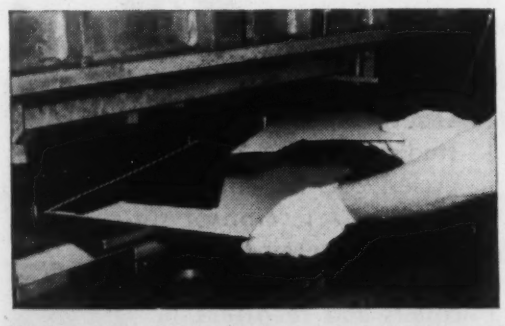
The outlook for 1958 is that total plastics production will probably end up slightly under 4½ billion pounds and that polyethylenes, polyesters and vinyls will again be the only materials to show substantial production in-

USE THE 'SELECTOR'—You will find properties of most engineering materials, plus names and addresses of suppliers, in M/DE's *Materials Selector* reference issue, published last September.

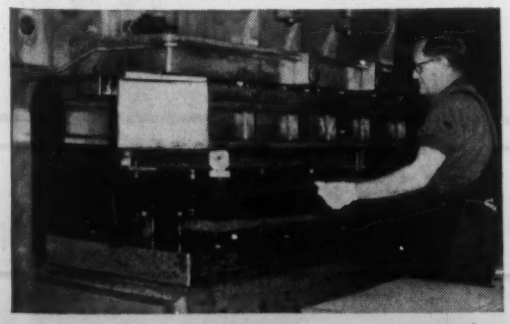

SELECT-O-MATIC 200
SEEBURG
"Perfect finish retained"
"This reject problem is licked"
"Downtime certainly has been reduced"
"Nothing more to be desired in quality and finish"
"Stands up very well under standard fabricating methods"

K. R. Craft, Vice President, The Seeburg Corp., Chicago, with one of the company's famous juke boxes. The brilliant reflectivity and durability of Nickeloid pre-plated metals is an important factor in the product's eye-catching good looks.

NICKELOID METALS SAVE 4 PRODUCTION STEPS— REDUCE REJECTS FOR THE SEEBURG CORPORATION



Standard fabricating methods are used to stamp and form juke box trim. Nickeloid Metals eliminate machinery tie-up; rejects are less than 1%.



Stamping Nickeloid chrome steel, protected with Mar-Not adhesive-backed paper which is easily peeled off. Finished part will need no polishing.

Pre-Finished Design Material is Easily Worked With Standard Fabricating Methods

The Seeburg Corporation uses Nickeloid *pre-plated* chrome steel to achieve functional beauty and attention-value . . . economically. Before switching to Nickeloid, the company did its own cleaning, plating and buffing. The job required four — sometimes five more operations than are now necessary. According to Mr. Craft, "The tremendous cost of plating and buffing was not only more expensive and much more time consuming, but the finished product had to be inspected, and the rejections on plated and buffed metals was very much higher than it is with Nickeloid. Economically, the Nickeloid Metals have proved themselves in production."

Using standard fabricating methods, Nickeloid Metals need only be stamped and formed — then assembled. By capitalizing on this pre finished *method* of production, this leading manufacturer has eliminated the machinery formerly required for plating, polishing and buffing — saved four or five production steps, and is producing a better end product *with less manpower*. Can you use these advantages in *your* operation?

14 finish-to-base metal combinations — sheets, coils, strips.

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AMERICAN NICKELOID COMPANY

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PRICES AND SUPPLY

creases. Production of high density polyethylene will continue to increase percentage-wise as compared to that of conventional polyethylene, and polypropylene production will begin to enter into the statistics. By the end of the year, Du Pont's new acetal plastics will be going on stream and shortly thereafter production of General Electric Co.'s polycarbonate plastics will be announced.

In general, says SPI, prices will tend to remain the same for at least the next six months. There will be some scattered changes but they will tend to balance out.

Stockpile Purchasing of Aluminum Altered

Revisions in stockpile purchasing contracts with major aluminum producers have been worked out by the U.S. Government. Chief feature of the change is to require that the companies deduct aluminum imported from Canada from amounts they bring to the Government for purchase.

The two firms chiefly affected are Aluminum Co. of America and Kaiser Aluminum and Chemical Corp. The original stockpile contracts, signed in 1950, 1951 and 1952, committed the Government to buy up to nearly 1.4 billion pounds of aluminum through 1958 in the event consumption decreased to a point where the metal could not be sold. In 1953, when the U. S. was short of aluminum, Alcoa and Kaiser contracted to buy 1.5 billion pounds through 1958 from Aluminum Co. of Canada. With consumption of aluminum at extremely low levels since last December, the major aluminum producers have been offering the metal to the Government every month since.

According to Sen. A. Willis Robertson, the revisions will save taxpayers "between $75 and $100 million."

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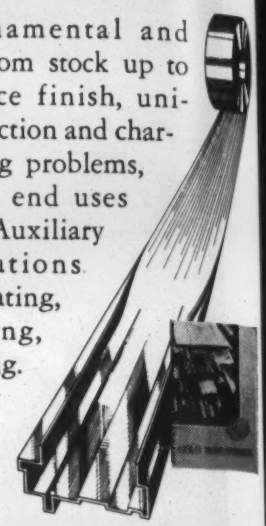

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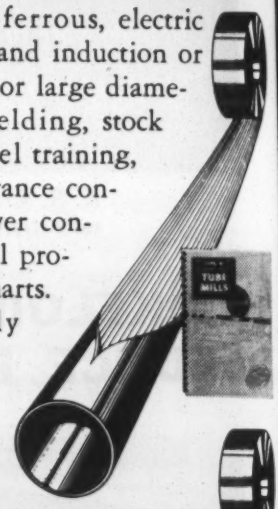

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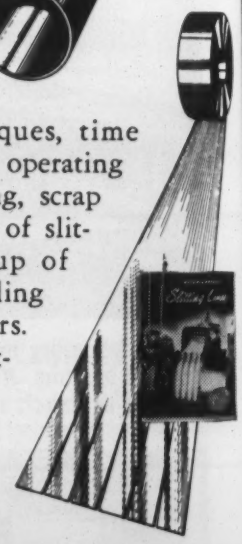
Operating techniques, time studies, analyses of operating cycles, coil handling, scrap disposal, selection of slitters and setting up of slitting lines, including coilers and recoilers. Advantages of slitting and how to compute "profit-point". 76 pages, fully illustrated.



Any or all of these books are free upon requests. Send for your copies today . . . Ask for them by title.

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Since these tapes come backed with vinyl or polyethylene film—or cloth coated with pyroxylin, vinyl or polyethylene—they fit into every packaging scheme.

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A significant announcement.

TO STIMULATE AND ENCOURAGE THE IMAGINATIVE EMPLOYMENT OF PLASTIC MATERIALS

THE BACHNER AWARD

. . . for excellence in the application of plastic materials, established by the CHICAGO MOLDED PRODUCTS CORP. and named to honor the Company's founders, is to be awarded in Chicago at the time of the forthcoming National Plastics Exposition. The Bachner Award is for an outstanding contribution to the practical application of molded and formed plastics to the products of industry. The winning company will receive an inscribed plaque, and the individual(s) designated by the company as being most responsible for the achievement will receive $1,000. Honorable mention citations will also be awarded. Entries must be received by August 15. Complete information and entry forms are obtainable from The Secretary to the Committee, Mr. William T. Cruse, c/o Society of the Plastics Industry, Inc., 250 Park Avenue, New York 17, N. Y.

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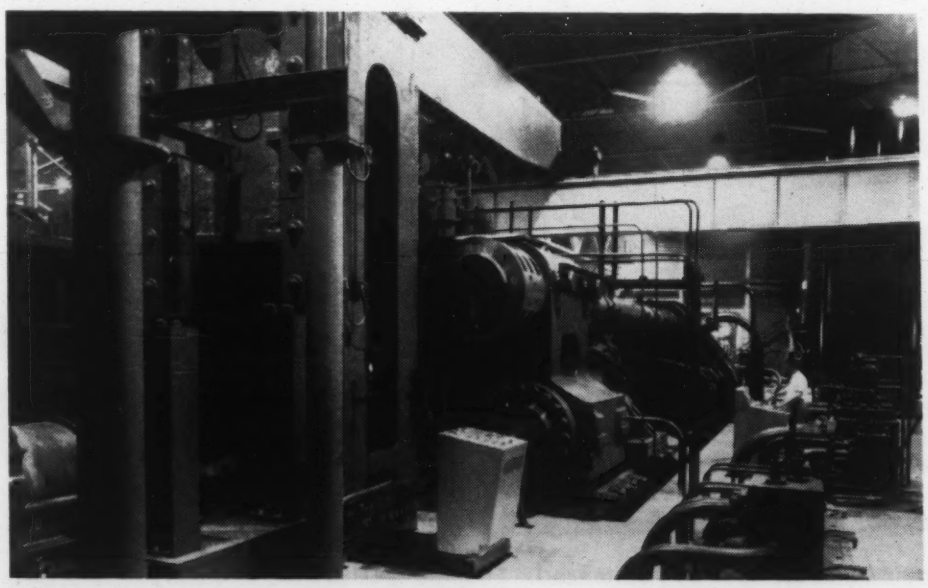
News OF INDUSTRY

Design Engineering Show Coming Next Month

The third annual Design Engineering Show and Conference—the only industrial exposition devoted exclusively to the design engineer's needs—is scheduled to be held Apr 14-17 at Chicago's International Amphitheatre.

The *Design Show,* held for the first time in 1956, is now considered to be the third largest annual exposition. Thus far, 410 individual exhibitors have reserved space to display such things as metals; nonmetallics; finishes and coatings; fasteners and adhesives; parts and shapes; mechanical, electrical and electronic components; power transmission systems; and various types of engineering equipment and services.

The *Design Conference,* sponsored by the Machine Div. of the American Society of Mechanical Engineers, will again cover most of the materials, mechanical and electrical aspects involved in product design. One of the highlights of the Conference will be the sessions devoted to engineering materials. Typical of the papers to be presented are: "Shock Resistance of Plastics," "Uncommon Engineering Materials," "Compatibility of Metals in Bearing Contact" and "Sandwich Materials." (See April issue of MATERIALS IN DESIGN ENGINEERING for complete program, list of exhibitors and details of registration.)



Largest extrusion press—Shown above is what is claimed by Harvey Aluminum to be the world's largest American-built aluminum extrusion press now in operation. The giant press is capable of exerting a force of 12,000 tons and is presently turning out aluminum structural shapes for aircraft, missile and commercial needs.

The new press has an overall length of 300 ft and weighs 4 million pounds. It can extrude aluminum sections from ingots 32 in. in dia and 75 in. long. Main advantage of the huge press is that it can produce large one-piece structural shapes to replace sections now assembled from smaller components. As a result, substantial savings in cost and time are achieved.

Transactions of AIME Published Bi-Monthly

The Metallurgical Society of the American Institute of Mining, Metallurgical and Petroleum Engineers has begun issuing its transactions as a separate publication. The publication, first issued in January, is bi-monthly and includes engineering and scientific papers covering activities of all three of the Society's divisions—Iron and Steel Div., Extractive Metallurgy Div. and Institute of Metals Div. Members of AIME are charged a subscription fee of $5 per year; nonmembers are charged $20 per year.

Improved Polymers Aim of Joint Research

National Lead Co. and Celanese Corp. of America have joined forces in a research program

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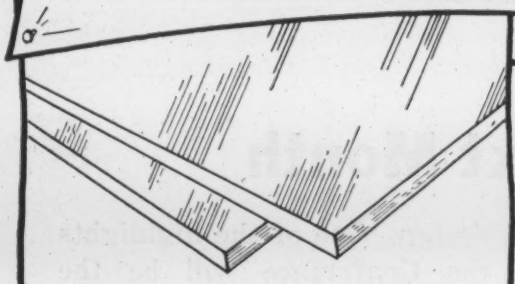

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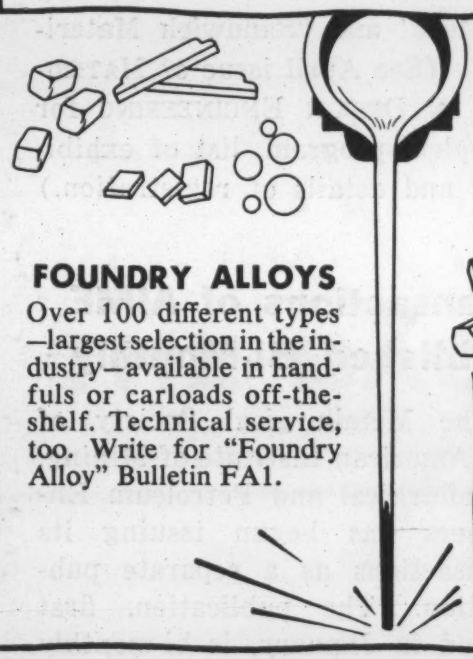
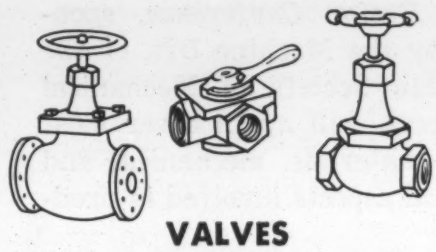
WELDING ROD

One-stop service for all you need in Aluminum, Copper Alloys, Nickel Alloys and all major types of welding rod and wire. A full line of soft solders and silver brazing alloys, too. Technical service and complete literature on request.



FOUNDRY ALLOYS

Over 100 different types—largest selection in the industry—available in handfuls or carloads off-the-shelf. Technical service, too. Write for "Foundry Alloy" Bulletin FA1.



VALVES

All major types are available from stock in Aluminum, Inconel, Monel, Nickel and Stainless Steel (and plastics, too). Write for descriptive literature.

ARCHITECTURAL SHAPES

Copings, gravel stops and door saddles are just a few of more than two hundred Alcoa aluminum shapes available off the shelf, and illustrated in booklet titled "Shapes." Monel, Stainless and Copper roofing items complete the Whitehead line of architectural materials on hand.

These "Plus Items" and many more are available in addition to a wide selection of corrosion-resistant sheet, rod and tube.

All told, there are more than 20,000 items distributed and serviced by Whitehead. All are available, off-the-shelf, from the nine Whitehead Metal "Supermarkets." All are the products of such leading producers as Alcoa, Anaconda, Inco & Crucible Steel to name just a few.

When you call Whitehead you get fast service, and frank, unbiased help in selection. Technical service when you need it. Add it up and you'll find it pays to

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For more information, turn to Reader Service card, circle No. 524

aimed at improving polymers for plastics and fibers through use of newly developed polymerization catalysts. The polymerization catalysts, produced by National Lead's Research Laboratories, are reported by the two companies to "constitute an important breakthrough toward successful production of improved polymers, including radically new types of polypropylene and polystyrene."

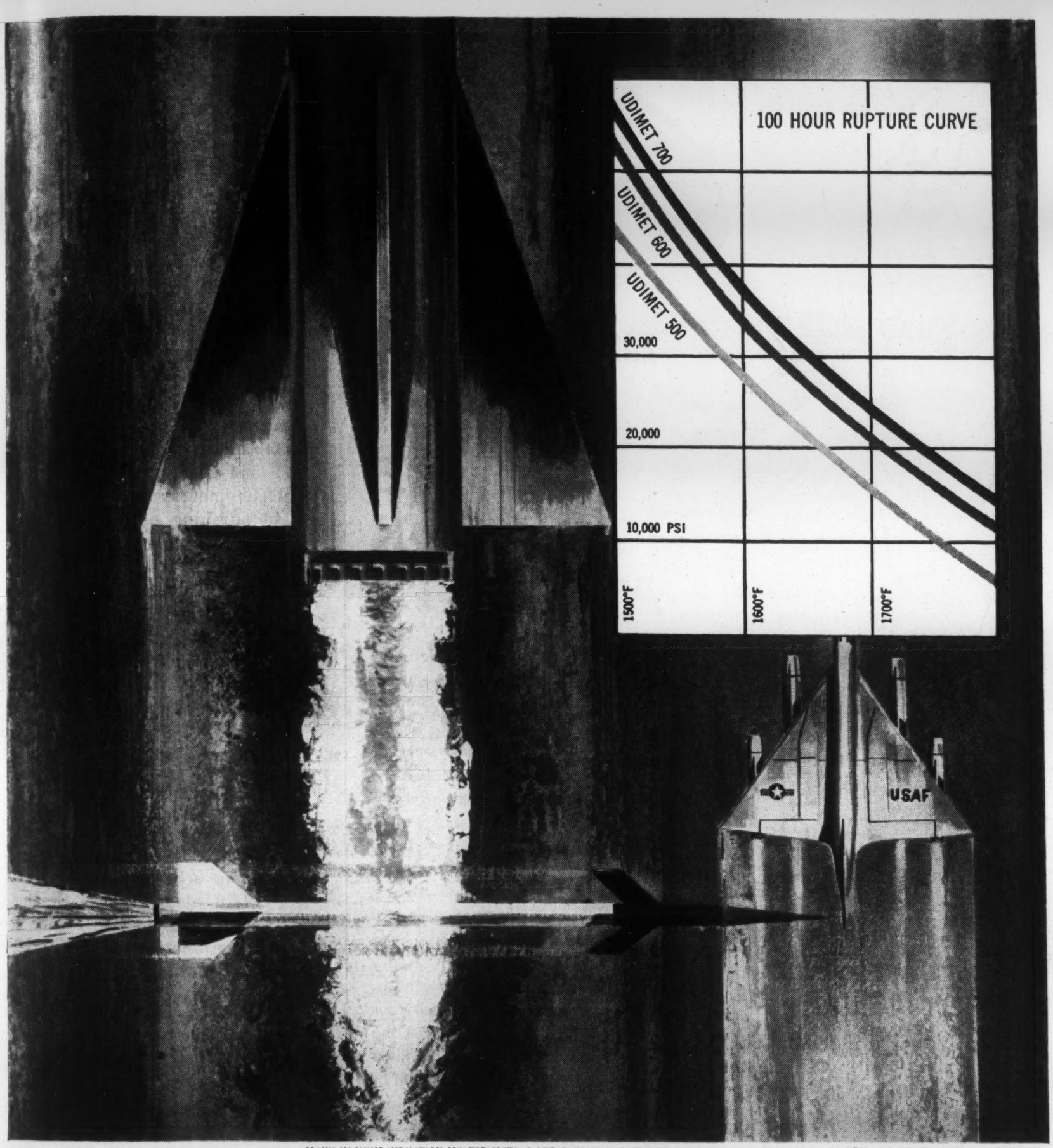
According to a statement issued by the two companies, much stronger, more highly heat resistant plastics can be developed by controlling the molecular structure of polymers. Currently, almost all polymer production is conducted under conditions that result in random linkage of molecules. The key to molecular control is said to lie in polymerization catalysts. Use of the new catalysts is expected to result in polymerizations that will provide more economical plastics and fibers with outstanding physical properties.

Concurrent research is now under way by the two companies: National Lead is working on the catalysts; Celanese is concerned with polymer processing.

Tool Engineers Plan Research Center

The board of directors of the American Society for Tool Engineers has approved the establishment of a member-industry service program whose provisions include: 1) a school and training center for tool engineers, 2) a research center with laboratory facilities, 3) increased technical publishing activities, and 4) ade-

PROPERTIES of most engineering materials can be found in M/DE's *Materials Selector* reference issue, published last September. Names and addresses of suppliers are also listed.



MANY VACUUM INDUCTION MELTED METALS AND ALLOYS CAN NOW BE PRODUCED IN HEAT SIZES UP TO 5,000 LBS. BY UTICA METALS DIVISION

announcing Udimet 600 and 700

for a wider range of applications at elevated temperatures!

With the development of these two new alloys, the Utica Metals Division of Kelsey-Hayes scores another materials "break through" with vacuum induction melting. Producible only by the vacuum induction melting process, *Udimet 600 and 700 surpass the elevated temperature properties of any other known alloy which can be produced in quantity for critical high-temperature, high-stress requirements.* They not only possess excellent stress-rupture qualities but also exhibit high tensile strength at temperatures above 1500°F.

Like Udimet 500, Udimet 600 is now available in production quantities. Udimet 700 is available for development applications. Write for complete information.

vacuum induction melting develops

- High-temperature corrosion resistance
- Increased ductility
- Extreme cleanliness
- Precise chemical control
- Longer stress-rupture life
- Increased tensile strength
- Better fatigue resistance
- Greater yield strength
- Greater impact resistance
- Greater creep properties

UTICA METALS DIVISION OF **KELSEY-HAYES**

KELSEY-HAYES CO. U DI MET ALLOYS UTICA 4, NEW YORK

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SOME ALLOYS COVERED BY U. S. PATENT #2809110

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TIME TO LOOK AT COSTS

You need the answers to such questions as:

"Can a TUBULAR RIVET replace a solid rivet, screw, or bolt and thereby accelerate production?"

"Would a SPLIT RIVET with a decorative head improve product appeal?"

"Should a SELF-PIERCING RIVET be used and eliminate a drilling operation?"

"Can a cold headed part such as a SHOULDER RIVET serve as a fastener and also provide a bearing surface?"

"Would a TAPPED RIVET, made to receive a screwed-on assembly, simplify field service?"

These are typical questions asked of Chicago Rivet engineers because keen competition today makes necessary re-examination of production methods. No matter how complex or how simple your fastening problem may seem to be, get the cost saving advice that Chicago Rivet engineers can give. Send blueprint or sample assembly—no obligation.

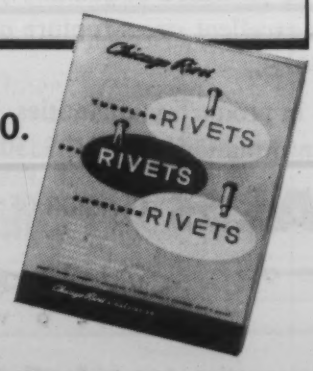
There are *Chicago Rivet* Machines that will set

1 Tubular or Split Rivets At a Time
2 Tubular or Split Rivets At a Time
3 Tubular or Split Rivets At a Time
4 Tubular or Split Rivets At a Time
5 Tubular or Split Rivets At a Time
6 Tubular or Split Rivets At a Time

Chicago Rivet & MACHINE CO.

965 S. 25th Ave. · Bellwood, Ill. (Chicago Suburb) · Branch Factory: Tyrone, Pa.

FOR YOUR FILES—Rivet catalog describing 1388 standard tubular and split rivets and 26 single and multiple automatic rivet setters.



For more information, turn to Reader Service card, circle No. 462

News OF INDUSTRY

quate space for headquarters operation.

According to Harold E. Collins, ASTE president, "We can now envision . . . a busy center of intellectual engineering activity which should help give birth to badly needed new technological ideas, as well as providing additional means for the interpretation and dissemination of basic tool engineering knowledge to those pursuing or engaged in a tool engineering career."

The results of preliminary investigations and a report of proposed plans are expected to be announced at the forthcoming ASTE Tool Show and Convention in Philadelphia this May.

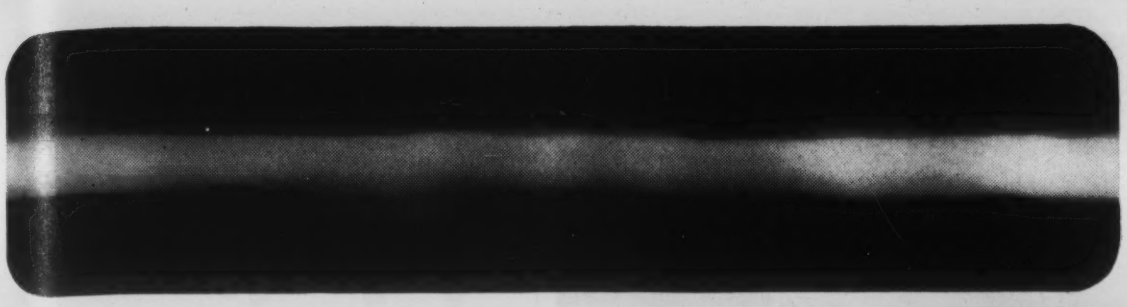
Welding Engineers to Meet in April

This year's national spring meeting of the American Welding Society is scheduled to be held Apr 14-18 at the Hotel Statler, St. Louis. The meeting will be held in conjunction with the sixth Welding Show.

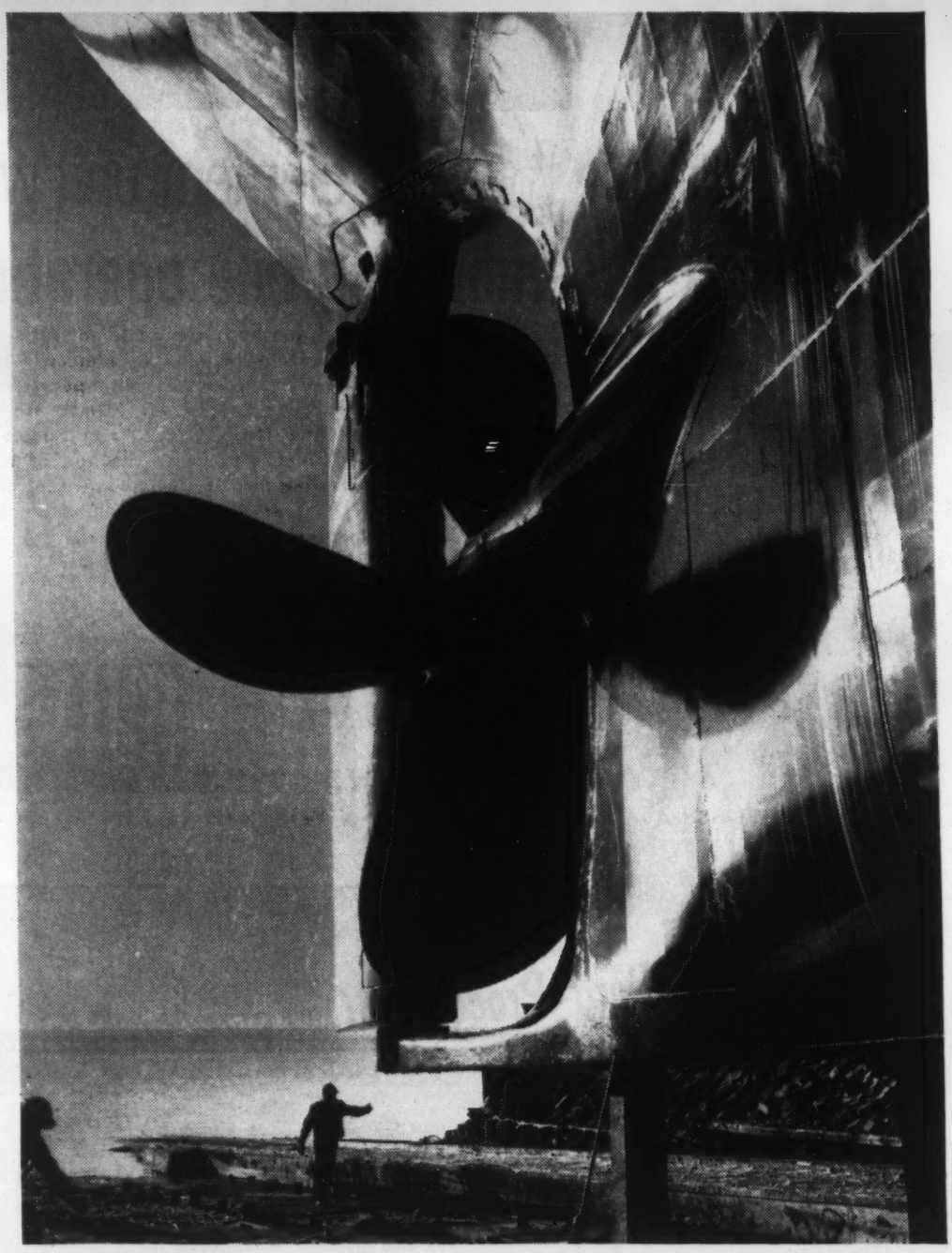
A total of 63 papers covering various aspects of welding will be presented by 95 authors at the 21 sessions planned for the meeting. Four of the session will be co-sponsored by the Metals Engineering Div. of the American Society of Mechanical Engineers. Twelve papers have been prepared for these sessions covering "Strength of Welds," "Mating of Structural Properties with Design," "Design and Materials for Low Temperature Applications," and "Casting Weldments."

The annual Adams Lecture of the Welding Society will be presented by Earnest F. Nippes, Rensselaer Polytechnic Institute. His subject will be "The Weld Heat-Affected Zone."

The Welding Show, expected to be the largest of the six thus far staged, will have about 115 exhibi-



Heavy sections like rudder posts and propeller blades can be gamma ray inspected with ⅓ shorter exposure—and welded seams can be radiographed more rapidly with available portable or low kv x-ray equipment—when Kodak Industrial X-ray Film Type KK is used.



. . . cut exposure time ⅓ with New Kodak Industrial X-ray Film TYPE KK

Where heavier sections are to be radiographed or where the output of available x-ray or gamma ray sources is limited, Kodak's new Industrial X-ray Film Type KK is the film to use.

This film shows as much as 50% increase in speed over the well-known Type K Film. It means more work can be done—that exposures can be cut by a third. And those who have tried Type KK tell us that its higher contrast, offsetting a slight increase in graininess, provides improved radiographic sensitivity.

To learn how Kodak Industrial X-ray Film Type KK can extend the service of your present radiographic equipment, get in touch with your x-ray dealer or Kodak Technical Representative.

EASTMAN KODAK COMPANY
***X-ray Division*, Rochester 4, N.Y.**

Kodak
TRADE MARK

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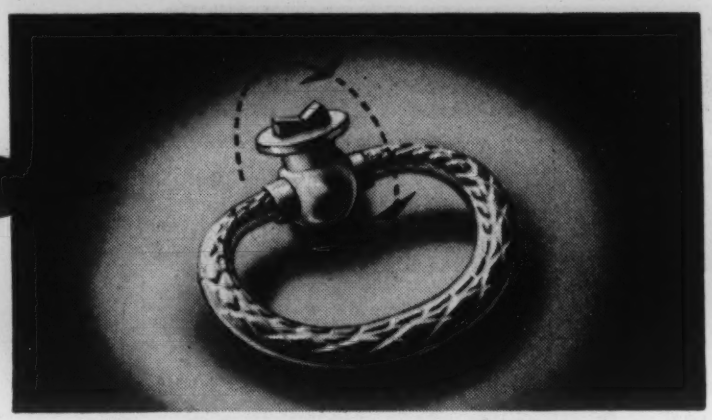
another unique GRC die cast zinc alloy component



this movable Intercast® element unit was cast-assembled in one operation by GRC

GRC's unique, patented method die casts multiple-part zinc-alloy INTERCAST units with moving elements in a single, automatic, time-saving, money-saving operation . . . even continuously interlocked assemblies. Units are delivered ready for use. This INTERCAST technique is an ingenious refinement of GRC's exclusive method of small parts die casting—providing broad design latitude, close tolerances, economies in quantities of 100,000 and more. Let GRC solve your problems. No size to small! Maximum length: 1¾", maximum weight: ½ oz.

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I-S Beryllium Copper compression springs are hardened after forming to a tensile strength of 185,000 to 220,000 psi. The resultant springs offer you many advantages . . .

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- close tolerances
- long endurance life
- resistance of corrosion
- stability at elevated temperatures
- reduced inspection and assembly costs
- less space required of springs

I-S Micro-Processed beryllium copper compression springs are the ideal springs for many applications . . . for pumps and valves — instruments and meters — relays — motor brushes — switches and many others.

Engineer's Assortment . . . 100 Micro-Processed beryllium copper helical compression springs—50 pairs—all different. Write for Bulletin No. 97-44—to help save time and money on development work.

For full info[illegible] Micro[illegible]mpression [illegible] write [illegible] your copy of [illegible] . . "Mic[illegible]ssed Spring[illegible] Copp[illegible]

Instrument Specialties Co Inc.

224 BERGEN BLVD., LITTLE FALLS, NEW JERSEY
Telephone: CLifford 6-3500

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News OF INDUSTRY

tors. Further information may be obtained from American Welding Society, 33 W. 39th St., New York 18, N. Y.

Engineers

Donald L. Colwell has been elected vice president in charge of laboratories and research, Apex Smelting Co.

John S. Light has joined National Research Corp. as director of the Mechanical Engineering Dept.

Dr. Lyman R. Fink has been appointed general manager of the X-Ray Dept., General Electric Co.

Charles A. Schulte has been named manager of Vanadium Corp. of America's new Vancoram plant. **Albert J. Primosic** has been appointed manager of the corporation's Niagara plant, replacing Mr. Schulte.

Robert A. Lubker has been appointed director of research, Alan Wood Steel Co.

Philip DiFalco is now chief engineer, LeMaire Tool & Mfg. Co.

Dr. Ernest R. Ramirez has been appointed research engineer in General Electric Co.'s Metallurgical Products Dept.

Robert S. Buffum has joined Borden Co.'s Chemical Div. as project engineer in the Polyco-Monomer Dept.

William R. Johnson has been named chief research metallurgist and **Richard J. McCluskey** chief machine design and development engineer, Associated Spring Corp.'s research center, Bristol, Conn.

Walter Kudlaty has been promoted to chief design engineer, Miller Fluid Power and Tru-Seal Divs., Flick-Reedy Corp.

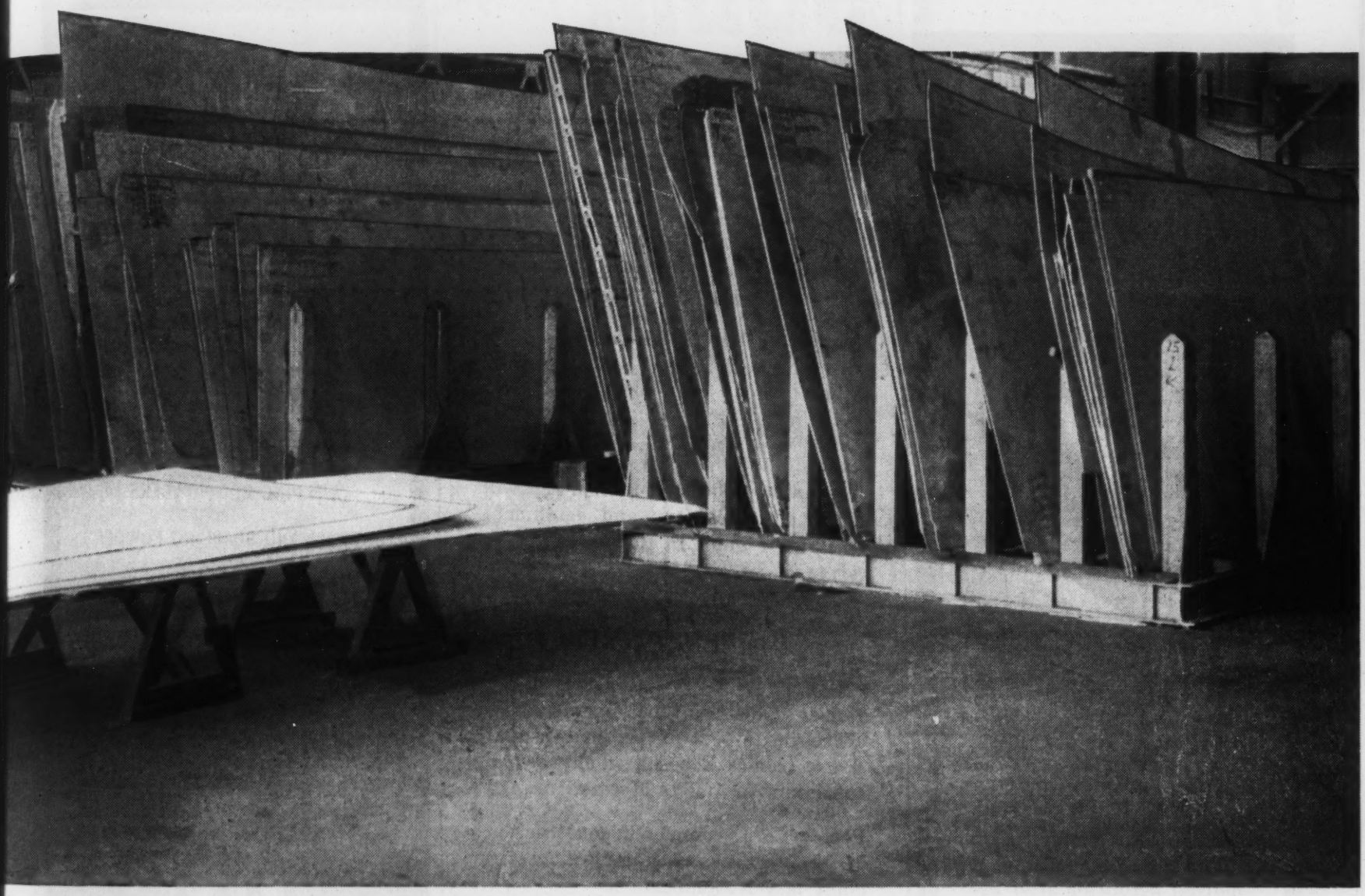
Dr. Nelson S. Marans has been appointed research chemist, W. R. Grace & Co.'s Research and Development Div.

Dr. Lowell H. Milligan has been appointed to the newly created position

For more information, circle No. 459 ›

Available now from Carlson

. . . any size and shape you want
in Types 405, 410 and 430 stainless plate



Carlson's stock of Types 405, 410 and 430 chromium stainless plate is the largest ever. You can order plates, large or small, and get delivery in a few days. Types 405 and 410 find wide application in petroleum processing. Type 430 is generally used for furnace parts, annealing boxes and nitric acid storage tanks. Consider the 400 series if you need stainless plates right now.

Prompt delivery isn't your only advantage. These grades cost less than chromium-nickel stainless steels and if you need irregular shapes and sizes, experienced men with specially designed equipment can cut your plates and get them out in a hurry. Carlson provides a complete service with a flexible operation to take care of your specific requirements. This combination of stock, specialization and service saves you time and money, *gives you what you want when you want it!*

G.O.CARLSON *Inc.*

Stainless Steels Exclusively

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PLATES • PLATE PRODUCTS • FORGINGS • BARS • SHEETS (No. 1 Finish)

You can
do more things
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better with
STACKPOLE
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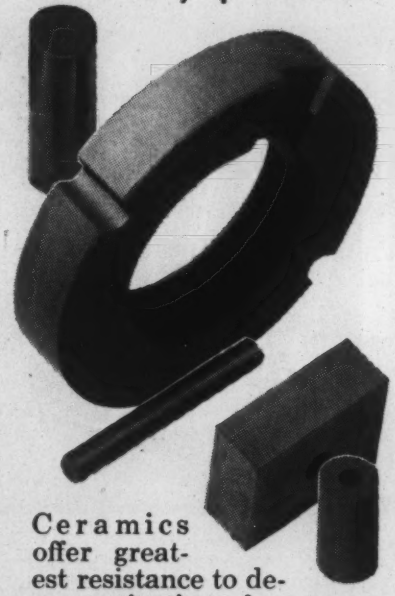
The permanent magnets
that
are really permanent



Ceramics offer greatest resistance to demagnetization of any commercial magnet material . . . All energy is fully usable—no keepers, pole pieces or auxiliary air gaps needed . . . Can be magnetized before or after assembly . . . Electrically non-conductive . . . Less heating . . . Inert to chemicals and gases . . . Up to 8 or more poles on a single flat face . . . AND MANY OTHER ADVANTAGES.

Write for Ceramagnet Engineering Bulletin RC-11A

STACKPOLE
CARBON COMPANY
St. Marys, Pa.

For more information, circle No. 417

News of Industry

of associate director of research and development, Norton Co.

Dr. B. D. Thomas has been named to the presidency of Battelle Memorial Institute. He succeeds **Dr. Clyde Williams**, whose retirement was recently announced.

Companies

Continental Machine Co. has moved to a new location at 2345 W. Nelson St., Chicago 18, Ill.

Ramo-Wooldridge Corp. has established a space technology laboratory, a new autonomous division of the former Guided Missile Research Div.

Young Spring & Wire Corp. is the new name of L. A. Young Spring & Wire Corp.

Howard Industries, Inc. has purchased the Universal Motor Div. of Westinghouse Electric Corp. and will move all machinery and equipment to its new plant in Racine, Wis.

Hydromatics, Inc. has recently transferred its operations to new facilities at 70 Okner Parkway, Livingston, N. J.

Kaiser Industries Corp. plans to purchase the assets of **Kaiser Aircraft & Electronics Corp.**, a wholly owned subsidiary of Willys Motors, Inc.

Pemco Corp. completed construction of its new research and development plant last November.

Gries Reproducer Corp. is expanding plant and production facilities which will more than double their output. Completion is expected early this year.

Conap Co. is a new research and development organization devoted to the formation and application of synthetic materials. The new company is located in Olean, N. Y.

Battelle Memorial Institute has been selected for the establishment of a nuclear radiation information center by the **U. S. Air Force.** The center will gather and disseminate data concerning the effects of nuclear radiation on materials and systems which

PLAST-IRON
POWDERS

ELECTROLYTIC AND
SPONGE IRON POWDERS

PREMIXED CU-NI-FE-POWDERS
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GROWTH CONTROLLED IRON POWDERS

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MODIFICATIONS
TO FIT YOUR NEEDS

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PM-5d

Send for Technical Data
and Working Sample

PM
PLASTIC METALS

PLASTIC
METALS

Division
National-U.S.
Radiator Corporation

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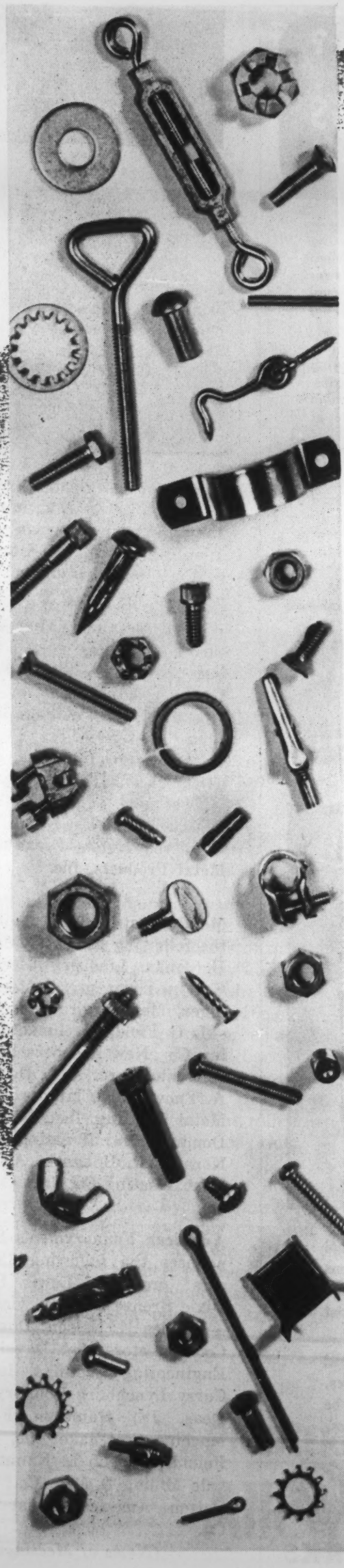

Fasteners made Stainless at low cost

Standard Industrial Fasteners and Other Steel Products Given Stainless Properties by the Modern Miracle in Metallurgy

ASC Metal Diffusion is a revolutionary new process that actually interchanges iron and chromium atoms to produce a chromium-rich surface that is an integral part of the parent metal. Not a plating, coating or cladding. Will not craze, crack, peel or chip. Resists wear. Resists corrosion. Resists heat. Good dimensional stability.

Easy-to-fabricate stock items can be up-graded to meet your own or your customers' demands for stainless qualities at reasonable prices. Send us samples of your fasteners — machined, stamped, upset or cast. We will process them at no cost to you. Write us today.

ALLOY SURFACES COMPANY

103 South Justison Street, Wilmington 1, Delaware
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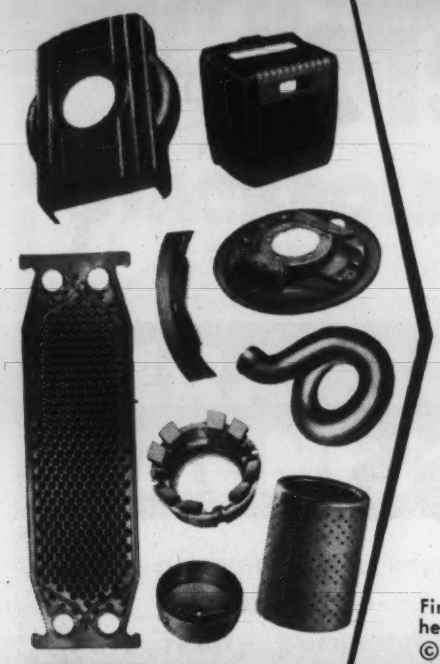
Production costs too high?
BOSSERT METAL STAMPINGS
offer many ways to reduce costs!



Whether your product is in the planning stage or in production, you can often reduce costs by using metal stampings for parts or complete assemblies. Complex forms can usually be produced with fewer operations, with holes punched to exact dimensional accuracy, eliminating separate drilling, machining and assembling.

Several parts can be combined in a single stamping, and you can take advantage of the weight-saving features of lighter metals and alloys without sacrificing strength or durability. Your present production costs can be reduced, too, with Bossert's superior quality and dependable service.

Design Engineering Service

Bossert's re-design service can help you develop stampings for parts and assemblies that are now being cast or forged or machined, usually with substantial savings in cost. Send us blue prints or samples for our recommendations.

Write for literature
Find out how our facilities can be helpful to you.
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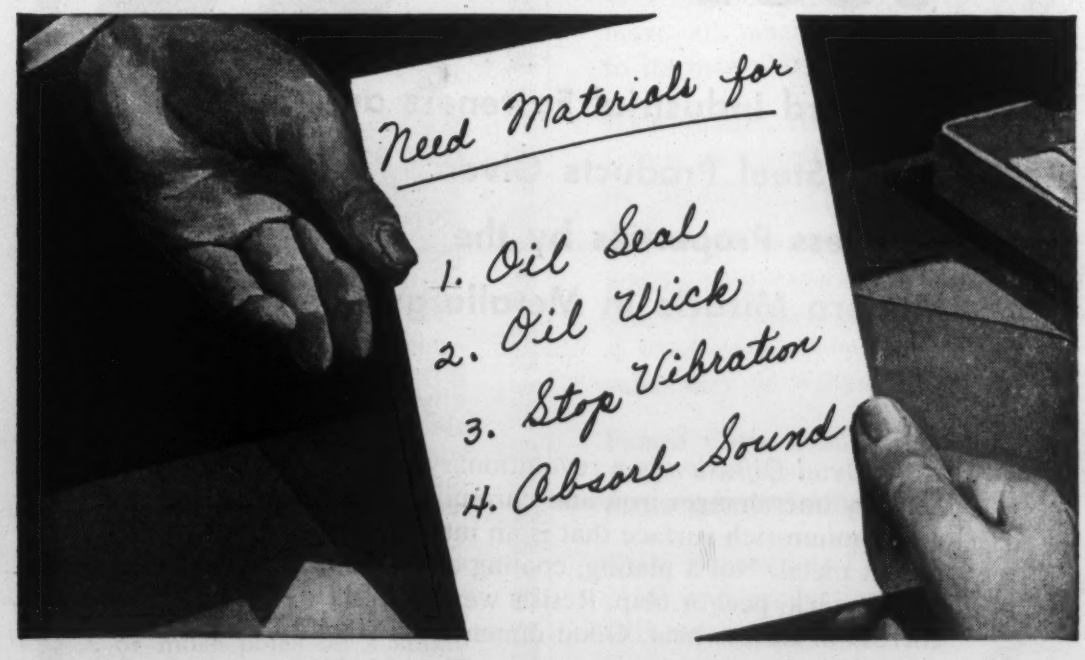

FOR ALL FOUR
YOUR BEST
ANSWER IS
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Western Felts can be made as soft as virgin wool or as hard as bone—or any desired specifications in between. But always, their live fibers hold their shape. They never ravel or fray . . . resist wear, age, and weather.

For over 56 years Western Felt has manufactured and cut specification felts for all industries. Whatever your problem, our experience can be helpful. Let our engineers investigate that possibility for you.

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WESTERN Felt WORKS
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Chicago 23, Illinois
Branches in all Principal Cities

may be required in aircraft of the future.

Chart-Pak, Inc., manufacturers of printed pressure-sensitive tapes and plastics, has acquired **Transograph Co.**

Societies

Society of the Plastics Industry, Reinforced Plastics Div., has re-elected James S. Lunn chairman of the executive committee. Mr. Lunn is president of Lunn Laminates, Inc.

Powder Metallurgy Parts Manufacturers Assn. has elected the following officers: president—Kenneth M. Gleszner, Dixon Sintaloy, Inc.; first vice president—William R. Toeplitz, Boundbrook Oil-Less Bearing Co.; secretary-treasurer—George L. Bachner, Yale and Towne Mfg. Co.

Two new companies elected to membership are: Eaton Mfg. Co., Powdered Metals Div.; and Powder Metal Products, Inc.

Metal Treating Institute has elected the following officers: president— K. U. Jenks, Lindberg Steel Treating Co., Inc.; vice president—A. T. Ridinger, Metallurgical, Inc.; treasurer —L. G. Field, Greenman Steel Treating Co. New members of the board of trustees are: A. L. De Hart, Fred A. Snow Co.; Clarence F. Graham, Metal Treating, Inc.; M. B. Dominy, Dominy Heat Treating Corp.; and Norman R. Hodgson, Alfred Heller Heat Treating Co., Inc.

American Foundrymen's Society announces the following 1958-59 officers: president—Lewis H. Durdin, Dixie Bronze Co.; and vice president —Charles E. Nelson, Dow Chemical Co. Directors are: David W. Boyd, Engineering Castings, Inc.; T. W. Curry, Lynchburg Foundry Co.; R. R. Deas, Jr., Hamilton Foundry & Machine Co.; Jake Dee, Dee Brass Foundry; Webb L. Kammerer, Midvale Mining & Mfg. Co.; and H. M. Patton, American Hoist & Derrick Co.

(News of Meetings on p 218)

For more information, turn to Reader Service card, circle No. 395

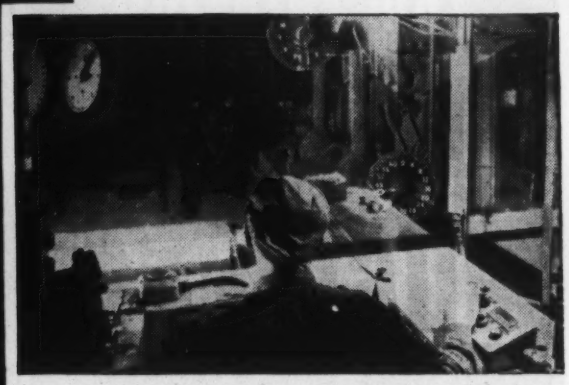
THE WORLD'S FIRST CARD-OPERATED MILL,

PROMISES YOU BETTER STEEL—AUTOMATICALLY

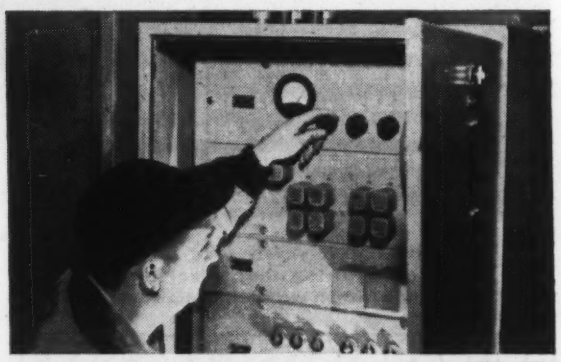
HIGHER QUALITY

MORE
UNIFORM SIZE

BETTER
PHYSICAL PROPERTIES



New method provides a large file of schedules for various types of steel.



General Electric engineers, working closely with AL personnel, developed and installed the control systems which regulate the mill.

Better quality, more uniform steel is the result.

A NEW punch-card control system, recently installed on the 56" universal roughing mill at Allegheny Ludlum's Brackenridge, Pa. plant, is advancing mill standards of quality control.

Here's how it works: Allegheny Ludlum rolling experts predetermine optimum rolling procedures for the type of steel desired and translate this data into punches on an IBM card. These punches represent the proper screwdown settings, mill speed and number of passes. When the mill schedule calls for it, the mill operator in the pulpit simply selects the proper card, inserts it into the card reader, and he is ready to roll. As the operator makes each pass, the mill is automatically adjusted for each additional pass required. The rolled material is held uniformly to desired dimensions, and day in, day out it proves to have better, more constant physical properties.

It's easy to see how this kind of progress fits into your interest in consistent high quality. By performing rolling operations exactly the same way time after time, this new unit further assures Allegheny Ludlum customers that they are getting the best possible product from the industry's pioneer producer.

Let us talk over your requirements with you. Write us, or call the Allegheny Ludlum sales office nearest you, and an AL sales engineer will help you with any problem. *Allegheny Ludlum Steel Corporation, Oliver Building, Pittsburgh 22, Pennsylvania.*

WSW 6628

PIONEERING on the Horizons of Steel

Allegheny Ludlum

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LONG WEARING
LOW FRICTION

UNIQUE (OIL-FREE)

SELF-LUBRICATING
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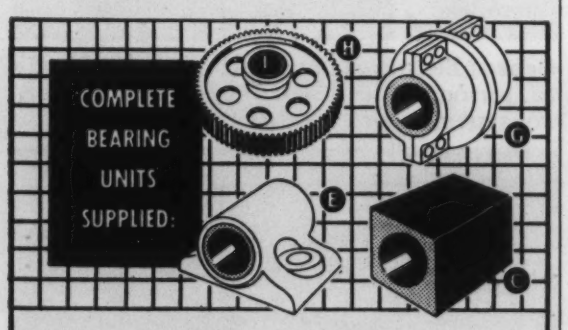
EXCELLENT DURABILITY • CONSTANT COEFFICIENT OF FRICTION • APPLICABLE OVER A WIDE TEMPERATURE RANGE (−450° to +700°F.) OPERATE DRY, OR AT HIGH SPEEDS SUBMERGED IN WATER, GASOLINE OR LIQUID GASES • NON-CONTAMINATING IN FOODSTUFFS • EXCELLENT FOR CURRENT-CARRYING BEARINGS

GRAPHALLOY is widely used for self-lubricating piston rings, seal rings, thrust and friction washers, pump vanes.



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News OF INDUSTRY

Meetings

INSTRUMENT SOCIETY OF AMERICA, eighth annual conference on instrumentation for the iron and steel industry. Pittsburgh. Mar 11-13.

SOCIETY FOR NONDESTRUCTIVE TESTING, conference on "Practical Applications of Radiographic Testing." Westbury, L. I., N. Y. Mar 12.

AMERICAN ROCKET SOCIETY and AMERICAN SOCIETY OF MECHANICAL ENGINEERS, joint aviation conference. Dallas. Mar 17-20.

NATIONAL ASSN. OF CORROSION ENGINEERS, annual conference. San Francisco. Mar 17-21.

INSTITUTE OF RADIO ENGINEERS, annual national convention. New York City. Mar 24-27.

SOCIETY OF THE PLASTICS INDUSTRY, INC., 15th annual Pacific Coast section conference. Palm Springs, Calif. Mar 26-28.

Design Engineering Conference, American Society of Mechanical Engineers, Machine Design Div. Chicago. Apr 14-17.

Design Engineering Show. International Amphitheatre, Chicago. Apr 14-17.

AMERICAN WELDING SOCIETY, annual meeting and welding show. St. Louis. Apr 14-18.

METAL POWDER ASSN., annual meeting and powder metallurgy show. Philadelphia. Apr 21-23.

ELECTROCHEMICAL SOCIETY, spring meeting. New York City. Apr 27-May 1.

AMERICAN SOCIETY OF TOOL ENGINEERS, 26th annual meeting and tool show. Philadelphia. May 1-8.

AMERICAN ELECTROPLATERS' SOCIETY, annual convention. Cincinnati, Ohio. May 19-22.

AMERICAN ROCKET SOCIETY, INC., semi-annual meeting. Los Angeles. June 8-11.

MALLEABLE FOUNDERS' SOCIETY, annual meeting. Hot Springs, Va. June 9-10.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, semi-annual meeting. Detroit. June 15-19.

AMERICAN SOCIETY FOR TESTING MATERIALS, 61st annual meeting and apparatus exhibit. Boston. June 22-28.

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His broad experience can help you solve many problems. But most important of all—he can acquaint you in detail with many special services offered by the mill. These include statistical quality control, nondestructive tubing inspection and testing, pilot and test lot sampling and melting, field specialist and specification services—there are many more.

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You will find that your Superior distributor has a modern steel service center equipped to meet all your requirements in tubing. He offers you:

- Small tubing in many analyses
- Wide range of sizes
- Tubing of highest quality for any applications
- Diversified stock
- Prompt price quotations and delivery
- Use of his warehouse for your firm's tubing inventory

For more information about Superior tubing, write for a free copy of Bulletin 40, "A Guide to the Selection and Application of Superior Tubing." Superior Tube Company, 2006 Germantown Ave., Norristown, Pa.

Superior Tube

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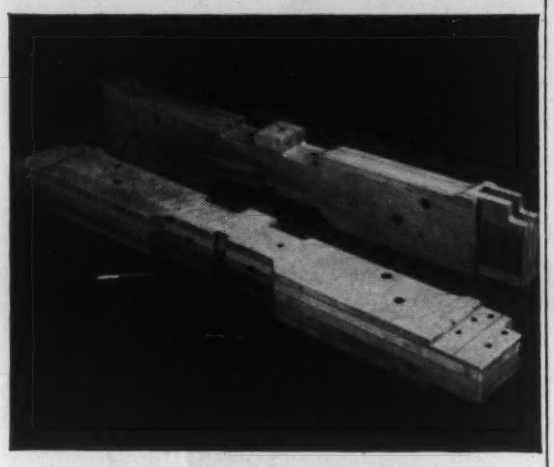
For more information, turn to Reader Service card, circle No. 533

WHAT'S YOUR WOOD PROBLEM?



Believe it or not— Gamble research even improves subway cars!

THE PROBLEM . . . A subway car manufacturer was having trouble with the contact shoe beams on cars. The solid wood beams (which hold the apparatus for picking up power from the third rail) were proving a headache because of too-high moisture content and too-low dielectric strength.

THE RESULT of Gamble development and testing: a laminated hard maple beam that is thoroughly dry, possesses high dielectric strength and holds perfectly to dimensional tolerances. Perhaps Gamble could help with *your* wood problem.

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This 28-page booklet describes Gamble facilities and services in detail. Includes many photographs of unusual products designed, tested and perfected by Gamble Brothers. Write for your copy today! Gamble Bros., Inc., 4627 Allmond Ave., Louisville 9, Ky.

GAMBLE BROTHERS
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If the problem involves WOOD —GAMBLE can help!

For more information, circle No. 527

TECHNICAL LITERATURE

(cont'd from p 45)

Books

Engineering Metallurgy. *Pitman Publishing Corp., New York. 1957. Cloth, 6 by 9¼ in., 536 pp. Price $7.50*

Forty professors engaged in teaching engineering metallurgy are co-authors of this book. Presented in a concise and understandable manner, the book emphasizes metallurgical principles rather than general handbook information. The book should be of particular value to both graduate and undergraduate engineers and to the newcomer in the field of metallurgy.

Chapter headings include: metallurgy and engineering; fundamental structure of metals and alloys; static properties of metallic materials; heat treatment of alloys by precipitation hardening; light alloys as engineering materials; the manufacture and composition of carbon and alloy steels; copper and copper-base alloys; special purpose steels; carbon and low alloy steels; cast iron; tool and die steels and cemented hard carbides; corrosion and oxidation; and effect of temperature on mechanical properties of metals.

Progress in Semiconductors: Volume 2. *Edited by A. F. Gibson, P. Aigrain and R. E. Burgess. John Wiley & Sons, Inc. New York. 1957. Cloth, 6 by 9½ in., 287 pp. Price $10.50*

Authored by experts in the field of semiconductor research, this book attempts to bring the reader up to date on new developments in semiconductor and luminescent materials. Subjects included in the current volume are: semiconductor alloys; properties of the III-V compound semiconductors; radiation effects in semiconductors; lifetimes of free electrons and holes in solids; the production of high quality germanium single crystals; impurities in germanium; high electric field effects in semiconductors; and theories of electroluminescence. Each article contains a bibliography.

Gray Iron Castings Handbook. *Edited by Charles F. Walton. Gray Iron Founders' Society, Inc., Cleveland, 1958. Cloth, 6 by 9 in., 620 pp. Price $10*

How can gray iron casting design be simplified to eliminate coring? What factors affect the cost of gray iron castings? When is alloy iron more corrosion resistant than stainless steel? Which iron should be

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Standard and custom grades of Graphite Specialties graphite are being employed as molds, dies, crucibles and piping in the production of titanium as well as for chlorinating a wide range of metals. Formulations with individualized properties are available, or "GRAPH-I-TITE" can be furnished.

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Components and equipment made from Graphite Specialties graphite grades can feature low neutron-capture cross section and high scattering cross section for moderator, reflector, fuel elements, structural parts and piping in nuclear reactors; seals, bearings and other mechanical shapes featuring temperature resistance to 5,000° F. and hardness to 5 Mohs; pipe and cylinders for electric furnace construction; processing equipment for difficult applications such as handling chlorine up to 5,000° F; and rocket nozzle inserts with a very low erosion rate.

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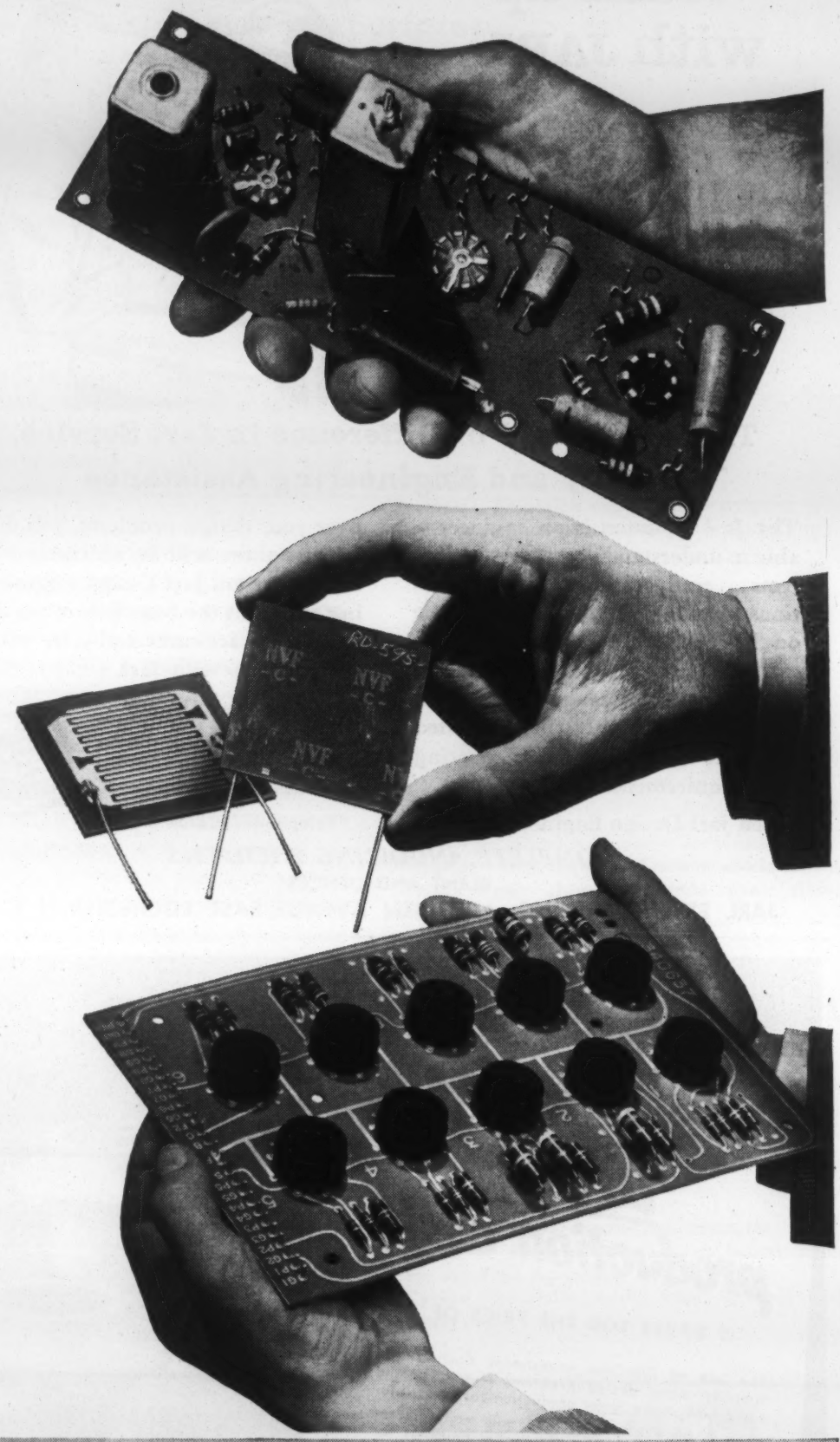

TYPICAL TEST VALUES ON COPPER CLAD PHENOLITE

GRADE	PROPERTIES OF BASE MATERIAL					COPPER CLAD PROPERTIES				RELATIVE COST
	Dielectric Constant	Dissipation Factor	Moisture Absorption	Flexural Strength	Maximum Operating Temperature	Copper Bond Strength		Hot Solder Resistance	Surface Resistance	Based on XXXP on Arbitrary Scale of 1
	10^6 Cycles	10^6 Cycles	1/16", % 24 Hrs	Psi	Degree F	Pounds to Pull 1" Strip		Secs to Blister 1" Square > Greater Than	Megohms, Etched Retma Comb Pattern, 96 Hrs/35°C/90% RH	1/16" Thk. 1 Oz. Copper 1 Side
						1 Oz	2 Oz			
P-214-B-1	5.3	.040	2.20	18,000	250	8	11	>10@ 475°F	100,000	.81
XXP-209-G-1	4.6	.037	1.30	17,000	250	8	11	>10@ 475°F	200,000	.92
XXP-239-1 PHENOCLAD	4.2	.035	0.67	15,500	250	8	11	>10@ 475°F	200,000	.92
XXXP-219-C-1	4.5	.030	0.70	15,500	250	8	11	>10@ 475°F	500,000-1,000,000	1.00
XXXP-455-1	4.0	.026	0.55	23,500	250	8	11	>10@ 475°F	1,000,000-1,500,000	1.00
XXXP-470-1	3.7	.027	0.48	14,000	250	8	11	>10@ 475°F	300,000-500,000	1.00
N-1-852-1	3.3	.030	0.20	16,000	165	8	11	>10@ 450°F	2,000,000	2.69
G-5-813-1	6.8	.018	1.00	55,000	300	8	11	—	—	2.98
G-10-865-1	5.2	.012	0.13	60,000	250	10	15	>30@ 500°F	1,500,000-2,000,000	3.49
G-11-861-1	4.9	.015	0.17	60,000	300	10	15	>30@ 500°F	2,000,000	3.55

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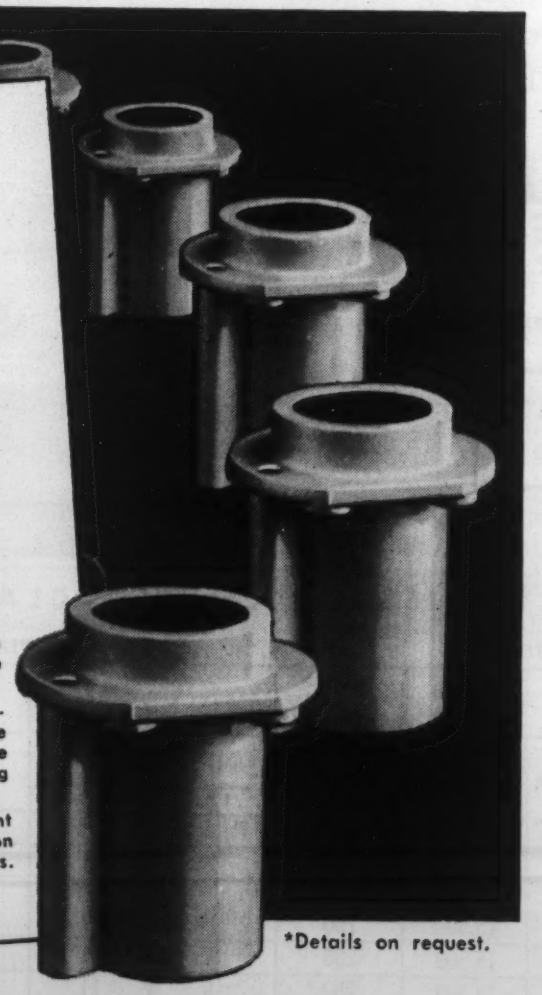
Here is an example of how one manufacturer now produces five control cylinder housings for his former cost to produce one.

Through the Precision Investment Casting process, 22 separate set-ups and more than 30 different machine operations formerly required to produce these control cylinder housings were reduced to 5 machine operations.

The advantages of Precision Investment Casting are many. Not only can it frequently save money in production costs, it also allows the use of harder alloys adding a distinct selling feature to the machine: longer life.

Write for the full story of Precision Investment Casting today. In it you may find the solution to some of your design or production problems.



*Details on request.

Send for our latest 12-page booklet, "Modern Precision Investment Casting." It gives you full details of the "how and why" of Investment Casting.

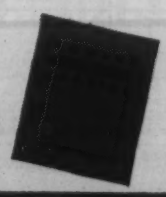


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Photo and data courtesy of Precision Metalsmiths, Inc.

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TECHNICAL LITERATURE

specified for a particular application? This handbook, through the effective use of graphs, charts and photographs, gives practical answers to these and hundreds of other questions about the design and use of gray, ductile, white and high alloy iron castings.

The broad scope of the book is readily discernible from the chapter headings. For example, there are sections on: 1) design of gray iron castings; 2) specifying and purchasing iron castings; 3) physical properties of gray, ductile, white and high alloy iron; 4) heat treating iron castings; 5) welding, joining and cutting; 6) machining and grinding; 7) metallic and nonmetallic coatings for iron castings; 8) functional and economical advantages of iron castings; and 9) a review of the history of gray iron.

Completely indexed, the book contains 411 illustrations and graphs, 64 tables, extensive bibliographies after each chapter, a glossary of foundry terms, and an index.

Reports

Permanent magnet BISMANOL, A NEW PERMANENT MAGNET. *E. Adams, W. M. Hubbard and A. M. Syeles, Naval Research Laboratory. May '52. 19 pp. Available from Office of Technical Services, Dept. of Commerce, Wash. 25, D. C. Price 50¢ (PB 121730)*

Properties of Wood PROPERTIES AND USES OF TROPICAL WOODS: PART 5. *Frederick F. Wangaard, W. L. Stern and S. L. Goodrich, Yale University School of Forestry. Dec '55. 145 pp. Available from Yale University School of Forestry, New Haven, Conn. Price $1 (PB 124527)*

Welding bibliographies BIBLIOGRAPHIES OF WELDING ARTICLES FROM 1937 THROUGH DECEMBER, 1957. *Available from American Welding Society, 33 W. 39th St., New York 18. Price $5 a set of 28, 50¢ a single copy.*

A comprehensive set of bibliographies of articles that have appeared in the *Welding Journal* during the last 20 years. Articles are grouped under 28 headings which include industries such as aircraft, railroads and shipbuilding; processes such as brazing, oxygen cutting, resistance welding and submerged arc

A Review of the Phosphate Coatings

Specified for the Protection of Metal Surfaces

By HUGH GEHMAN, Assistant Manager, Product Development Dept., AMERICAN CHEMICAL PAINT COMPANY

Phosphate coatings are protective inorganic finishes that actually change the chemical nature of metal surfaces. The metal reacts with the applied phosphate solution to form a nonmetallic, crystalline coating which serves to:

- **Improve paint adhesion**
- **Provide protection against corrosion**
- **Increase lubricity of friction surfaces**
- **Facilitate mechanical deformation of metals**
- **Decorate—in many instances**

Satisfactory protection of steel, zinc and aluminum surfaces against corrosion, paint peeling and blistering, and hard wear requires precision methods of chemical conversion coating.

Types of Conversion Coatings

There are seven classes of chemical conversion coatings commonly specified and used throughout industry today. They are as follows:

Zinc-iron phosphate (ACP Granodine®). This is the heaviest type of coating (gray in color) used for prepaint treatments on steel, iron and zinc surfaces. The process requires five or six operations: cleaning; rinsing; rust removal, if necessary; coating; rinsing; and a second rinse. Coating weight ranges from 100 to 600 mg per sq. ft.

Medium or large volume production of automobile bodies, appliances, projectiles and cabinets can be handled effectively.

The coating solution improves paint adhesion by forming a crystalline deposit over the metal surface. This deposit is rough, as revealed microscopically, and so offers an ideal gripping surface for paint particles.

Manganese-iron phosphate (ACP Thermoil-Granodine®). This is a heavy black coating used on friction surfaces to prevent galling, scoring and seizing of parts. Typical metal parts treated are pistons, piston rings, gears, cylinder liners, camshafts, tappets and various small arms components.

Iron phosphate (ACP Duridine®). This is a comparatively new process that places a light coating on surfaces for improved paint adhesion. Since cleaning and coating occur in the same bath, it has only three to five stages.

The iron phosphate treatment is a spray process suited for medium to large volume, large or small work. Precleaning is normally unnecessary, an economy factor in its favor.

Products protected by this process are steel or iron fabricated units, such as cabinets, washing machines and refrigerators. Weight of coating is 50 to 100 mg per sq. ft.

Zinc phosphate (ACP Lithoform®). This is a crystalline coating produced on galvanized iron and other zinc surfaces—also cadmium—for improving paint adhesion. The purpose of the coating is to provide a paint-gripping surface and to prevent the reaction between acidic components of the paint and the zinc metal, with the formation of soaps and loss of paint adhesion.

This coating is applied in weights of 75 to 500 mg per sq. ft. There are no limitations on volume or production or on size of products treated. Zinc phosphate coating is used on zinc alloy die castings, zinc or cadmium plated sheet or components, hot dip galvanized stock, and Galvanneal.

Amorphous phosphate (ACP Alodine®). This is a relatively new protective coating for aluminum and aluminum alloys. It may be used in place of anodic deposition for improved paint adhesion and corrosion resistance.

This coating is practical for production in any volume. Coating weight is 100 to 600 mg per sq. ft. Products treated include helmets, belt buckles, aircraft and aircraft parts, bazookas and rocket motors, roofing and siding. Particularly good when aluminum is painted prior to forming.

Zinc-iron phosphate for oil absorption (ACP Permadine®). This is a relatively heavy coating adapted to the retention of rust-inhibiting drying or nondrying oils and waxes on ferrous metal surfaces. The coating is applied to a weight of 1000 to 4000 mg per sq. ft.

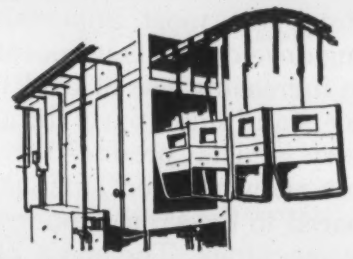
The process is satisfactory for large or small work in any volume—nuts, bolts, hardware, guns, tools, etc.

Zinc-iron phosphate for metal forming (ACP Granodraw®). This is a specialized coating used in conjunction with a suitable lubricant to facilitate the cold mechanical deformation of steel. The coating acts as an anchor for the lubricant throughout drawing, extrusion, and cold forming operations.

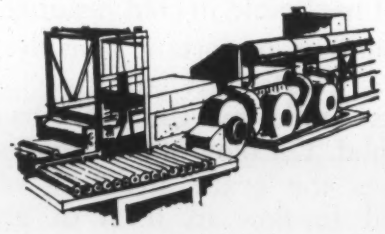
It is a successful treatment for products such as blanks and shells for cold forming, heavy stampings, impact extruded shapes, drawn wire and tube.

For more complete information about any one or all of these chemical conversion coatings, contact an ACP sales representative or write us at Ambler, Pa.

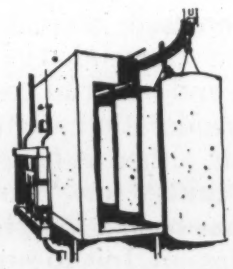
Typical Installations of Phosphate Coating Systems



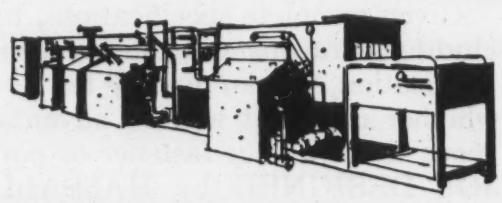
Customer: Truck manufacturer
Problem: Preparing cab parts for painting
Cycle: Phosphate wash; phosphate wash; rinse; chromic acid rinse; dry



Customer: Aluminum screen manufacturer
Problem: Final finish of aluminum shade screen
Cycle: Wash; rinse; phosphate coat; rinse; chromic acid rinse; dry



Customer: Water heater manufacturer
Problem: Preparation of water heater shells for synthetic enameling
Cycle: Phosphate wash; rinse; chromic acid rinse; dry



Customer: Hardware manufacturer
Problem: Preparing hardware parts for painting
Cycle: Wash; rinse; phosphate coat; rinse; chromic acid rinse; dry

CHEMICALS ACP PROCESSES

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New Chemical Horizons for Industry and Agriculture

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Cold Heading Cuts Costs

Fasteners and Small Parts Show Big Savings

One of the most important cost cutting developments in recent years is the increasing use of cold headed fasteners and small parts throughout industry. Parts produced by this process show marked savings when compared to the same production on screw machines. The most obvious advantage is in the economical wire stock used in cold heading. The more expensive bar stock used in the screw machine method results in considerable waste, whereas the waste is almost negligible in cold heading.

Another important consideration is the greater strength structure of parts made by the cold heading method. The blow of the heading tool causes the grain structure of the metal to flow in lines of greater strength whereas the strong outer surface of the screw machine product has been reduced to scrap.

The possibilities of cold heading are almost unlimited when used in conjunction with secondary operations. The tremendous savings in operation and material costs make it a must consideration when designing small parts either as fasteners or as integral units for manufactured parts. It has been a long time policy of John Hassall, Inc. to support their cold heading equipment with the latest methods of secondary manufacture. Machines for roll threading, slotting, drilling, tapping and many other operations are available for your profit.

Given complete specifications, including a drawing and an idea of the application, we can quickly tell you whether or not it will be advantageous to have your fastener or part JOB-DESIGNED by HASSALL. The remaining important aspect of our service to you is the ability to get into production quickly and make prompt shipment.

Write for a copy of our new booklet, "What the Designer Should Know about Cold Heading."

John Hassall, Inc.

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TECHNICAL LITERATURE

welding; and metals such as aluminum, cast iron, copper, molybdenum and zirconium.

Creep, rupture curves GENERALIZED MASTER CURVES FOR CREEP AND RUPTURE. *G. J. Heimerl and A. J. McEvily, Jr., Langley Aeronautical Laboratory. Oct '57. 31 pp. Available from National Advisory Committee for Aeronautics, 1512 H St., Wash. 25, D. C. (TN 4112)*

The materials included in this study are pure aluminum, 2024-T3 aluminum alloy sheet, 7075-T6 clad aluminum alloy sheet, carbon molybdenum steel, 18-8 Cb stainless steel and Inconel X. The master curves shown are for rupture life, minimum creep rate, and 0.2 and 0.5% creep strain.

Brazing of aluminum THE BRAZING OF ALUMINIUM AND ITS ALLOYS. *June '57. 36 pp. Available from Aluminium Development Assn., 33, Grosvenor St., London, W. 1, England. Price 30¢ (Bulletin No. 22)*

Describes the principal methods of brazing aluminum, such as flame, furnace and flux dip. The properties of aluminum and some alloys suitable for brazing are tabulated.

Electroforming waveguides ELECTROFORMING OF WAVEGUIDE COMPONENTS FOR THE MILLIMETER-WAVELENGTH RANGE. *Albert A. Feldmann, National Bureau of Standards. Nov '57. 16 pp. Available from Supt. of Documents, U. S. Government Printing Office, Wash. 25, D. C. Price 15¢ (NBS Circular No. 587)*

Ferromagnetic materials NONMETALLIC FERROMAGNETIC MATERIALS. PART 7: MICROWAVE FERRITES. *H. C. Tothenberg and E. B. Mullen, General Electric Co. Dec '55. 49 pp. Available from Office of Technical Services, Dept. of Commerce, Wash. 25, D. C. Price $1.25 (PB 131053)*

Information on nonmetallic ferromagnetic materials for use in communication equipment. Discusses theoretical considerations and measurement techniques.

Transistors Subjected to Heat, Cold and Humidity

. . . in this Cincinnati Sub-Zero Environmental Test Unit.

Custom-built to specifications, a new model SU-40-8-HC Cincinnati Sub-Zero test unit is providing vital product data at Federal Telecommunications Laboratories, Palo Alto, California. Used to test transistors and other electronic components, it is adjustable from minus 50° to plus 200° F., while maintaining a relative humidity of 95% between plus 80° and 160° F. Compact and portable, it is ideally suited for a variety of test applications.

Model SU-40-8-HC

If you must have specific product reaction data at various temperatures, altitudes, humidities, etc., outline your requirements to us for a no-obligation recommendation on a unit built to your needs.

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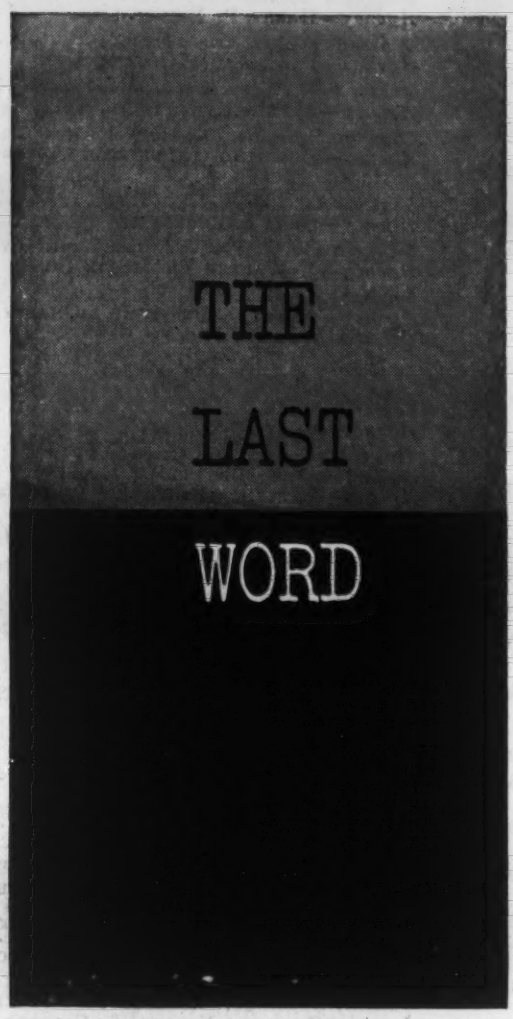

by ***H. R. Clauser,*** *Editor*

Back to the Movies

For a while it looked as though theater-goers might someday sit on their popcorn and eat it too. Because of the Air Force's interest in it as a cushioning material, popcorn (unbuttered and unsalted) was subjected to extensive engineering tests. Unfortunately, the popcorn didn't show up too well. It was too stiff, and it wasn't bouncy enough under compressive loads.

With movie attendance declining, the popcorn producers were probably also disappointed with the test results. But all may not be lost. Because of popcorn's high hygroscopicity there is still a chance that it might serve as a blocking material for moisture-proof packages. My personal experience munching soggy popcorn over the years definitely indicates that this is a promising field of application.

A Necessary Nuisance

At the head of the article starting off our feature section this month (p 96) is a tired and harassed engineer looking at a bewildering array of standards and specifications. In a way, the picture symbolizes the fact that standards are both a necessity and a bothersome nuisance. We need them to give us common reference points to use in choosing and evaluating materials. And they provide us with an exact technical language without which there would be crippling confusion. But at the same time the tremendous number and variety of standards sometimes threatens to cause more confusion than the standards themselves are designed to eliminate.

We hope the series of six articles beginning in this issue will help avoid some of this confusion entailed in searching for and using standards. The articles are being written by S. A. Kaidanovsky, who is well qualified for the job. He has been in the standards field—both in government and industry—for over 30 years. He has spent over six months gathering material for this series. And he tells us that he is beginning to feel like a recluse, what with standards and specifications stacked to the ceiling in his study and overflowing into the living room.

Immaterialisms

▸ The following two epigrams hang on the walls of the Value Engineering Dept. at Stromberg-Carlson Co.:

"There is no limit to what can be accomplished if it doesn't matter who gets the credit."

"Are you trying to help with the solution or are you part of the problem."

▸ There has been much talk lately about a greater exchange of information and data among technical people. I'm all for it. But I would also like to advocate a wider exchange of half-formed ideas, hunches, apparently useless insights, and even half-baked ideas. They seldom appear in reports and often die for lack of the right nourishment. Yet they are the amorphous sparks that often lead to big new advances. Perhaps what we need are more bull sessions, more coffee breaks and longer lunch hours, which seem to be the occasions most conducive to "blue sky" ideas.

▸ Here is what might be termed an unintentionally uncomplimentary complimentary letter which we received on our Joining and Fastening Plastics Manual (Jan '58). It read in part: "It is . . . excellent and complete . . . It is well organized . . . It has good balance . . . (and) it has no technical accuracies."

▸ *Flash*—After 14 years the Defense Dept., at the urging of Congress, has released a secret document titled "Silent Flashless Weapons." The heretofore hush-hush report covers a World War II bow and arrow project and includes technical descriptions of bows and arrows, many similar to those used by medieval crossbowmen.

▸ "The science of figures (is) . . . not only indispensably requisite in every walk of civilized life; but the investigation of mathematical truths accustoms the mind to method and correctness in reasoning, and is an employment peculiarly worthy of rational beings."—*George Washington.*